THE MAGAZINE OF

MEASUREMENT and CONTROL

INSTRUMENTS

TRANSMITTER ROOM, STATION KOA, DENVER, COLORADO
Courtesy General Electric Co.

X-RAY DIFFRACTION *Page 133*

TEMPERATURE CONTROL *Page 129*

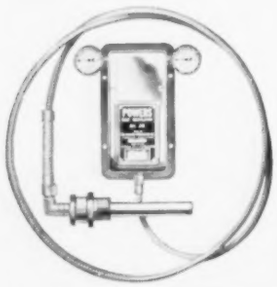
LOAD TESTING *Page 137*

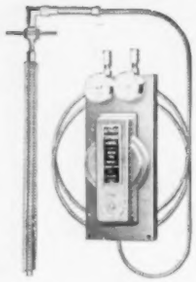
VOLUME 9

MAY 1936

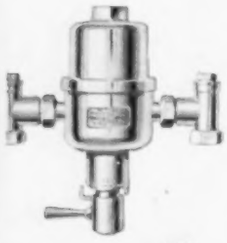
NUMBER 5

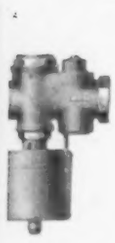
ir Operated Controls

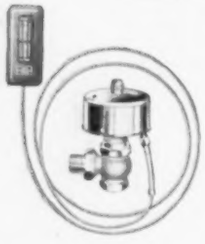


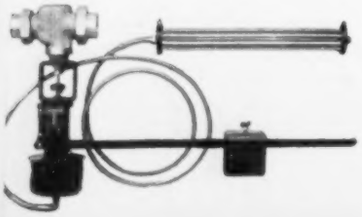


Self Operated Controls









Where can you use these Money Savin

COMBINATION TEMPERATURE REGULATORS

No. 11 Self Operated Regulator with Dial Indicating Thermometer

No. 26 Air Operated Regulators with Recording Thermometer

with Dial Indicating Therm

● To simplify the installation of automatic temperature control take advantage of the convenience and economy obtained with Powers combination regulators. They make it easy to quickly adjust the regulator to accurately maintain any desired temperature.

● Where extreme accuracy is required use the Powers No. 26 Regulators shown above. They are air operated and have a full throttling range from positive on and off control to very gradual control which prevents "hunting" and enables them to accurately regulate heating or cooling mediums in exact accord with the individual requirements of any control problem.

● May we send you bulletins describing these or any other of our many types of temperature or humidity Controls? The Powers Regulator Co., 45 Years of Automatic Temperature and Humidity Control. Offices in 44 Cities —See Your Phone Directory — 2720 Greenview Avenue, CHICAGO — 231 East 46th Street, NEW YORK—1808 West Eighth Street, LOS ANGELES—106 Lombard Street, TORONTO.

POWERS

TEMPERATURE AND HUMIDITY CONTROL

For Heating • Cooling • Air Conditioning • Industrial Pr cess

Quicker Response

THE MARK OF THE CHAMPION SPRINTER . . .

THE FEATURE OF THE MODERN AUTOMOBILE—

...AND A VITAL PART OF SEPARABLE WELL TUBE SYSTEMS *with Taylor Thermospeed*

QUICKER RESPONSE, *a built-in feature of* **NEW TAYLOR THERMOSPEED** *construction, sets new speed records in transmitting bulb temperature changes . . .*

IT'S getting off his mark faster that brings a sprinter within reach of a championship . . .

It's quicker starting in traffic that puts the modern car in a class ahead of previous models . . .

AND it's *quicker response* to temperature changes at the bulb that puts the Taylor Thermospeed construction for separable well tube systems out in front of other types of temperature responsive systems.

Quicker response at the bulb means that a recording thermometer gives a truer and more accurate picture of temperature.

Quicker response by Taylor Thermospeed means that temperature controllers can provide closer regulation.

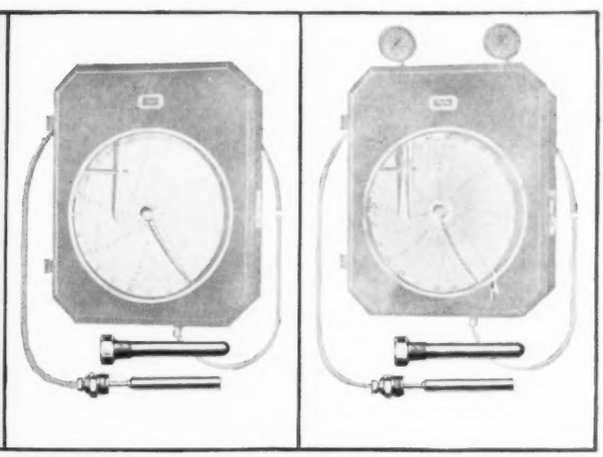
Taylor Thermospeed means that, in connection with separable well systems, Taylor Recording Thermometers and Temperature Controllers can operate more effectively than before. Yesterday these Taylor instruments were outstanding in accuracy, efficiency and durability. Today their accuracy and efficiency have been stepped up to new heights.

Improved accuracy is due very largely to another big advantage in Thermospeed construction. Conduction of heat from the bulb to the mounting wall is greatly decreased so that the bulb responds only to the temperature of the surrounding fluid being measured. Thus the factor which has contributed to inaccurate performance of conventional designs has been recognized and conquered in Taylor Thermospeed.

If you are interested in having separable well systems that operate with modern effectiveness, use Taylor Thermospeed in connection with Taylor Recorders and Taylor Controllers. Let us give you all the facts about Thermospeed. You'll want to have them. Ask a Taylor Representative, or write to Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada. Manufacturers in Great Britain—Short & Mason, Ltd., London, England.

TAYLOR THERMOSPEED MAKES THESE TAYLOR INSTRUMENTS OPERATE EVEN FASTER AND MORE ACCURATELY THAN BEFORE

Showing Taylor Recording Thermometer, and Taylor Fulscope Recording Controller with Thermospeed construction. Taylor Engineers contribute again to the more efficient and economical control of plant operations and product quality.



Taylor

Indicating · Recording · Controlling

TEMPERATURE, PRESSURE *and* **FLOW INSTRUMENTS**

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

CONTENTS · MAY 1936

Front Cover: Transmitter Room at KOA
Courtesy General Electric Co.

Temperature Control 129
with reference to heat flow through walls
By Emerson M. Pugh

X-ray Diffraction 133
at industry's service
By Victor Hicks

Load Testing 137
on underground cables
By George B. Stanton

Cathode-ray Tube Auxiliaries 140
Eleventh part of Oscillography series
By R. R. Batcher

Sources of Error 143
in electrical measuring instruments
By Perry A. Borden and M. F. Béhar

INSTRUMENTS' READERS AT WORK
No. 8—James G. Pratt 122

NEW INSTRUMENTS 123
Indicators, recorders, controllers, inspection devices, etc., for the plant and laboratory

OTHER DEPARTMENTS, etc.

EDITORIAL COMMENT 121
INSTRUMENTS' BOOK SHELF . . . . . 132 & 136
MANUFACTURERS' NEW LITERATURE 148
ADVERTISERS' INDEX 148
BUYERS' GUIDE 150

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Published Monthly on the 15th by
The Instruments Publishing Company
1117 Wolfendale Street Pittsburgh, Pa.
JOSEPH J. VIGNEAU, President
RICHARD RIMBACH, Vice-Pres.-Treas.

Branch offices
Boston: James Condon, 6 Marlboro St.
New York: Edwin F. Ripley, 118 E. 28th St.
Chicago: R. Farnham, 201 Wells St.
Glendale, Calif.: W. McIntyre, 1115 Tyler St.

Annual Subscription: U. S. $2.00. All other countries $3.00 *payable in advance* (remit by New York draft).

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Entered as second-class matter January 26, 1932, at the post office at Pittsburgh, Pa., under the Act of March 3, 1879.

INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

Page 122. A few days after this issue is put in the mails the great Petroleum Exposition will open its gates at Tulsa. In the oil industry, therefore, we sought a subject for this month's personality sketch. It was not necessary to fly to far-off oil fields, for *Instruments* has charter subscribers nearby in the engineering, executive, production and research groups of the petroleum industry. To Gulf's photographers (Johnson & Johnson Co.) a bouquet for snapping Jim Pratt exactly as we saw him at work.

Page 123. Why so few "New Instruments" items? No, not because any descriptions went into the editorial waste basket: as often declared on this page, this *never* happens! Our guess is that manufacturers were so busy filling orders that they had no time to bring out new devices—or no time to prepare the technical descriptions which, for your sake, we always insist on.

Page 129. Last November, at Pittsburgh University's Conference on Industrial Physics, we heard Dr. Pugh tell of air-conditioning research. At one point we nearly shouted with delight, for the new formulas he was presenting applied to many industrial temperature control problems. We buttonholed him. Result: read it for yourself.

Page 133. At that same Conference, Dr. Hicks told what X-rays can do for industry. The latter part of his talk sounded as if it could be worked up into an article you would find profitable. Dr. Hicks accordingly did work it up.

Page 137. Charter Subscriber Stanton modestly conceals, in his article, references to his own advance of underground-cable engineering. He has patents on new forms of testing instruments which represent, in our opinion, remarkable advances.

Page 140. Ralph Batcher continues describing CRO auxiliaries. More coming for several months.

Page 143. And under Electrical Measurements and Control there is concluded a handy treatment of errors, based on Perry Borden's rounded-out experience.

TWOFOLD PROBLEM

"COORDINATION of Boiler Auxiliaries" is the title of the excellent paper by A. F. Spitzglass and G. K. O'Connor presented at the Midwest Power Conference on April 23. "Coordination" is the *mot juste.* Lack of functional coordination among the devices which directly control fuel, air, feed-water, etc., makes a boiler difficult to control manually or automatically.

Boiler auxiliaries may be likened to the muscles of the body: even such a simple action as rising from one's chair involves nice timing and correct ratios of local forces. Modern boiler control instruments are capable of (1) continuously measuring all essential factors with satisfactory accuracy and (2) issuing proper commands to auxiliaries. Some control systems include well-disciplined aids: servo-motors commanded by instruments that possess the qualities of efficient leadership. But even the best headquarters-group of commander and aides cannot do much with soldiers who are not only individually awkward but likely to get in one another's way in action. The trouble with many "unsuccessful" applications of automatic control probably lies in auxiliaries interfering with one another. Spitzglass and O'Connor give examples of characteristic curves demonstrating that auxiliaries should be suited not only to the boiler but to one another.

We go further and declare that feed-water, fuel and air auxiliaries should be selected which will *obey* the automatic control system, because they are subordinate muscles whose value is measured by their subservience to the brains on the control board.

A heretical statement? Perhaps. But we fear no reprisals, for none followed our utterance of an equal heresy four years ago at the end of the Pittsburgh ASME-ESWP Joint Meeting on Combustion Control: It had fallen to our lot to sum up all papers and we concluded as follows:

> . . . A requisite for the attainment of automatic control is what may be called "controllability" . . . in order to make it possible for control instruments to . . . bring about better results. Manufacturers of steam-generating equipment and auxiliaries have failed to make them adequately controllable . . . When boilers and auxiliaries will be controllable, automatic combustion control systems will work to the satisfaction of everyone!

The usual procedure is firstly to specify auxiliaries whose individual "rangeabilities" and other characteristics seem to suit the boiler, and lastly to challenge instrumenticians to supply a system that will make them work harmoniously. This procedure should be reversed. The problem, then, is twofold: coordination of *things*; and team-work among *men*.

No. 8

JAMES G. PRATT

Head Instrument Man Neville Island Refinery of Gulf Refining Company

By M. F. BEHAR

GEOGRAPHICALLY, Neville Island is simply an island on the Ohio River about fifteen miles from Pittsburgh. Industrially, its name is associated with several outstanding enterprises. One of these is the Neville Island Refinery of the Gulf Refining Company. This modern refinery covers approximately one square mile, where the visitor loses himself in a labyrinth of huge stills and towers interconnected by a formidable number of pipes conveying liquids, vapors and gases at various pressures and temperatures.

A modern oil refinery resembles the human body which depends for its health on a brain and on numerous regulating glands. At Neville Island, the brain and the regulating glands are located on an 80-ft. control board to which is devoted the upper floor of a special two-story building. Half of the ground floor space is given over to the Instrument Department's office and repair shop; the other half to electrical equipment: for each instrumental control application there is a unit panel.

Over this central control board and its auxiliaries presides the subject of this month's sketch, assisted by three instrument men. Thanks to this central brain, the entire refinery "runs itself" 24 hours a day. This is apparent as one enters the 60x100-ft. pump house located about 100 feet away from the instrument house, and remains there a few minutes: each of the sixteen pumps speeds up and slows down under command of some instrument on the control board.

The reliance placed on instrumental control is evidenced by the fact that *there is no night shift of instrument men!*

James G. Pratt is six-foot-three tall (without the "iron hat" for which he is famous). He was born in Texas in 1901 but something Southern, rather than Southwestern, about him made us ask him about his family and, sure enough, he said that his ancestors had lived in Kentucky for many generations. These ancestors, no doubt, could shoot the spots off a card at fifty paces, but this is 1936, and so Jim Pratt uses recorders and controllers as his weapons, and his markmanship consists in keeping all processes "on the line."

He has been in the oil industry all his life, starting in the oil fields, where he learned to handle geophysical instruments. Transferred twelve years ago to Gulf's Fort Worth Refinery, his skill with instruments came under the notice of Leroy Barnett who made him his assistant. In 1931 he was chosen to be put in charge of the instruments at the new Neville Island Refinery. It may be said that the fact that there is no night shift of instrument men reflects not only the company's confidence in modern instruments but also Superintendent M. J. Ball's confidence in Jim Pratt himself.

Asked whether he was the one who specified instruments and control equipment, he modestly replied that this was all done at the main office of the company. "Are you consulted on these purchases?" we asked, and he admitted that he was. "Has it ever happened that the company purchased any instrument or control system different from the one that you specified when you were consulted?" He tried to be modest, but he had to admit that such a thing had never happened!

Yes, Jim Pratt knows instruments. His knowledge is far greater than that of an instrument mechanic: in some respects it is more valuable than that of a university graduate. Much of it he "picked up" and much of it he gratefully credits to his many years of studiously reading *Instruments*.

JIM PRATT'S INSTRUMENTS

TEMPERATURE	
Industrial thermometers	24
Gas-filled, pressure-spring type, round-chart recorder-controllers	9
Single-point, strip-chart, potentiometer recorder-controllers	3
Multi-point, strip-chart, potentiometer recorder-controllers	34
PRESSURE	
Indicating gages	250
Recorders	12
Non-indicating regulators (self-op.)	17
Indicating controllers (air-op.)	3
FLOW	
Positive meters	16
Recorders	61
Recorder-controllers (air-op.)	19
LEVEL	
Indicating controllers (air-op.)	5
Recorder-controllers (air-op.)	3
REMOTE MANUAL CONTROL	
Self-synchronous systems	5

TESTING

Instead of mercury thermometers, one portable standard potentiometer is used to check temperature recorders. Dead-weight testers (0-300 & 0-3000 lbs./in.^{2}) for checking pressure instruments. Mercury-column and water-column manometers for checking flowmeters. Meggers, voltmeters, etc.

SPARES

Complete pressure gages and pressure elements. For all other instruments, Jim Pratt carries parts based on the relative frequencies of serving determined by his experience

THE MONTH'S NEW INSTRUMENTS

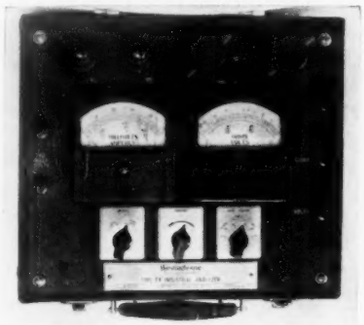
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

D-c. Industrial Analyzer

A new self-contained analyzer for making practically any type of d-c. voltage, current or resistance test with minimum connections, particularly suited for testing industrial motors and control, consists of an ammeter and a volt-ohmmeter with suitable shunts, multipliers and range changing switches all mounted in



one case ready for use. Three built-in shunts provide current ranges of 7.5, 75 and 750 amps. Self-contained resistors provide voltage ranges of 0 to 750 volts. Ohm ranges are 0-200 and 0-20,000. Suitable selector switches are provided for convenient selection of ranges. A standard No. 6 dry cell is employed to energize ohmmeter circuit. 50-millivolt terminals of ammeter are brought out to binding posts on front panel for use with external shunts when capacities other than those built in the unit are required. Ammeter is equipped with a follow-up pointer for measuring motor starting currents. A pair of 8-ft. shunt leads is supplied. Micarta front panel carries all measuring elements and details, and entire assembly may be removed from case for inspection by removing four screws. —*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Inspection Polariscope

To meet growing demand on the part of purchases of large quantities of glass articles or of important glass equipment, this new polariscope has been developed especially for performing inspections with utmost convenience. Experience is unnecessary: article to be inspected is merely placed on top surface. Strains show in the usual brilliant colors, even when room is not darkened, and can be seen by several observers simultaneously. Apparatus can be set up anywhere. It accommodates glass vessels in sizes up to that of a 1-gal. bottle, but larger vessels can be inspected by passing them along the viewing top. Cabinet height is 45"; finish is walnut. —*R. Fuess, Inc., 245 W. 55th St., New York City.*

Combustion Safeguard

An improved line of "Protectoglo" equipment (see *Instruments*, Vol. 5, Jan. 1932, page 20) includes two separate and distinct types of relays; and the flame-sensitive electrode can also be used as a special spark plug for electric ignition. Standard primary controller and motor valve complete the system of combustion safeguard. Thermionic tubes rectify and amplify power input which, when conducted from electrode unit to ground

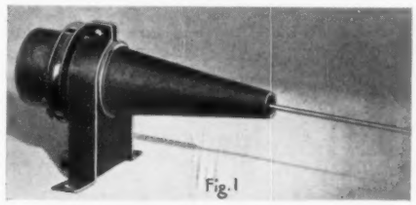


Fig. 1

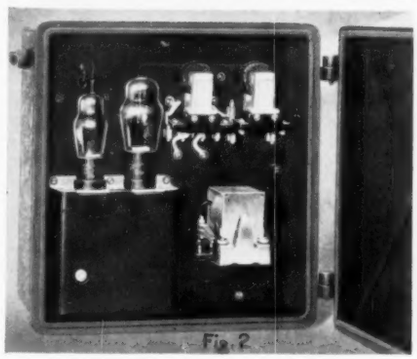


Fig. 2

through the flame, operates relay units controlling the operation sequence, main fuel valve, etc. Any interruption in circuit to ground through flame (flame failure) causes instantaneous and positive shut-down. Cast-iron dust and moisture-proof relay cases are of the universal type for either front of board or flush mounting. Standard radio type vacuum tubes are used, located in relay case under lock and key. Relay can be located in any remote location with reference to electrode unit. Terminal board is located in a separate moisture-proof chamber in relay case. Electrode unit contains no moving parts. A system of combustion safeguard can be supplied for practically any type of burner equipment. —*The Brown Instrument Co., Div. of Minneapolis-Honeywell Regulator Co., 4482 Wayne Ave., Philadelphia, Pa.*

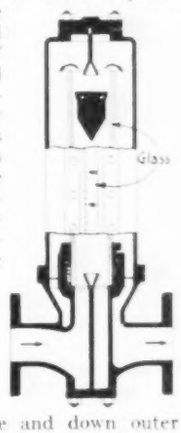
A-f. Transformers

A complete line of high fidelity audio transformers and reactors, known as "Super High Fidelity Series A," includes units for practically every purpose in the electronic field. Each unit has a frequency response of within ±1 db. from

30 to 12,000 cycles, is mounted in a completely reversible through-type case, is fitted with electrostatic shields between windings and is designed for extremely low insertion loss. The majority of the transformers in this line weigh 2 lbs. and measure $2\frac{3}{4}" \times 2\frac{1}{8}" \times 2\frac{7}{8}"$. Core type construction is said to render them free from hum and pickup. In illustration, use of mirrow brings out new sub-panel mounting.—*Ferranti Electric, Inc., 130 W. 42nd St., New York City.*

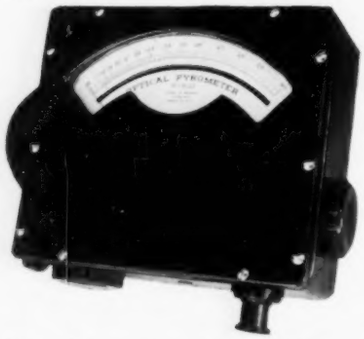
High-pressure Rotameter

For indicating flow-rate of corrosive liquids, vapors and gases at pressures making hazardous the use of conventional forms of Rotameters in which tapered glass metering tube is exposed, "Balanced Pressure Rotameter" has this tube enclosed in metal housing provided with two heavy sight-glass windows suitable for pressures <1500 lbs./in.^{2}. These two viewing slots being diametrically opposite each other, position of rotor can be seen satisfactorily at all times, provided only that metered fluid be sufficiently transparent. Fluid passes up through central metering tube and down outer annulus, so that pressures are balanced. —*Schutte & Koerting Co., 12th & Thompson St., Philadelphia, Pa.*



Optical Pyrometer

Employing disappearing-filament principle, this self-contained instrument is said to incorporate the first noteworthy advances made in optical pyrometer design in the past ten years. Its principal features are a direct-reading scale which obviates the need of comparison charts, and a bridge circuit which obviates the



need of a suppressed-zero milliammeter and at same time balances out effects of variations in room temperature. Filament of standard lamp forms one arm of bridge circuit, which is so adjusted that it balances when standard is at 1500°F., and galvanometer pointer is so set that at this temperature (null point) it is at bottom of scale, there being no "stop." Sensitivity of galvanometer is so adjusted that full-scale deflection will be produced by the unbalanced emf. when standard lamp is at temperature desired for upper limit of temperature range of instrument. Every scale is hand-calibrated against the factory standard lamp which is periodically checked against primary standards. "Model B-1" is scaled 1500-3000°F.; "Model B-2" has two ranges: 1400-2500°F. and 2200-3800°F. Current supply regularly consists of two ordinary dry cells but for continuous use an aluminum case is available, containing large long-life dry cells.—*Hurl R. Adams, Alhambra Way, Pittsburgh, Pa.*

H_2S Detector

Comprises an aspirator bulb, a detector tube and a movable scale graduated in $\%H_2S$. Operation consists of aspirating the bulb a number of times, thus drawing gas sample through detector tube into rubber bulb and forcing spent sample out other end of bulb. Glass detector tube contains a white, granular

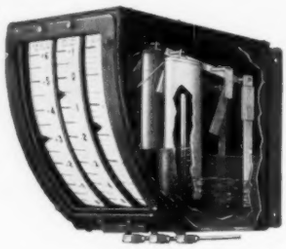
chemical of predetermined quantity and grain size, held in place in tube between two plugs of glass wool. Surface of granules reacts with any H_2S present in sample and turns dark gray, beginning at end where sample enters. When bulb has been aspirated proper number of times, length of travel of this discoloration is proportional to concentration (up to 0.04%). Chemical used in detector tubes is selected for its sensitivity to H_2S and its freedom from channeling. Its accuracy is said to be unaffected by temperature of sample, or by presence of other common gases or moisture.—*Mine Safety Appliances Co., Braddock Ave. and Thomas Blvd., Pittsburgh, Pa.*

BAILEY METERS

Accurately

Guide and Regulate Process Operations

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These gages are available with any number of pointers and any scale combinations from one to twelve. Actuating mechanisms may be oil-sealed bells or diaphragms.



Multi-Pointer Gage

Boiler Meters for recording combustion conditions and guiding boiler operators.

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids.

Recorder-Controller

Recorders for temperature, pressure, draft, speed and other factors.

Coal Meter

Granular Material Meters for accurately measuring the flow of coal or other granular materials in gravity chutes from overhead bunkers. The total quantity of granular material is shown on a large illuminated counter which may be easily read at a distance of 50 feet.

Control Systems for combustion, flow, pressure, temperature and other factors.

Complete information on any of the above Bailey Products will be gladly furnished upon request.

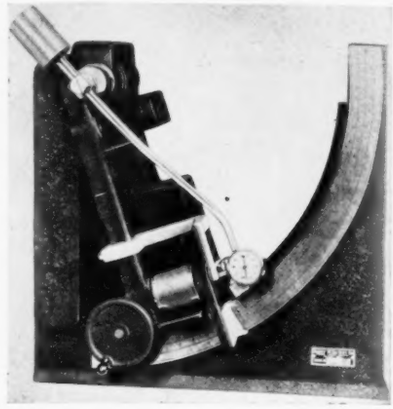
G-2

BAILEY METER COMPANY

1041 Ivanhoe Road • Cleveland, Ohio

Sand Deformation and Resilience Tester

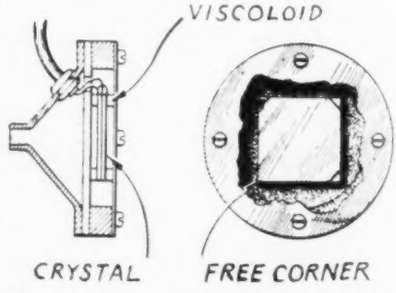
A new accessory for Universal Sand Strength Machine, which adds to value of compression strength test: deformation test readings are multiplied by the compression test reading to obtain the Sand Resilience value which figure is



used to determine whether the sand has good life or whether it is "short" and "brittle." Consists of an aluminum arm, pivoted at fulcrum point of pusher arm and weight, and of a dial indicator, mounted on free end so that its stem bears against the stud of compression test head, while its body is connected to pusher arm through an automatic releasing arm. This makes it possible to measure the amount that sand specimen decreases in length or deforms at instant when it breaks. A factor termed Sand Resilience takes into consideration both strength and deformation, to indicate amount of work required to break the sand. It is calculated by multiplying the green compression strength reading by the reading of the deformation indicator. —*Harry W. Dietert Co., 676 W. Grand Blvd., Detroit, Mich.*

Vibration Pickup

Employing a Rochelle salt crystal as a piezoelectric element, this new unit is designed and constructed (see illustration) for the study of vibrations as such, rather than for acoustical purposes. Its



frequency range extends from 10 to 3000 cycles and its distinctive characteristic is that by reason of inertial ("free corner") principle the crystal sensitivity varies nearly as the square of the frequency, permitting study of low-amplitude vibrations in upper part of range. At any one frequency, output is directly proportional to vibration amplitude. Output at 250 cycles is approx. 0.25 volts per 0.001" amplitude. Weight complete is 8 oz.; diam., 3"; depth, 1½".—*RCA Parts Div., RCA Mfg. Co., Inc., Camden, N. J.*

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New "Model 1200" Volt-ohm-milliammeter contains twin instrument having separate a-c. and d-c. movements. An

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Said to be "designed to measure sound levels exactly as heard by the human ear," new Model 300 Sound Level Indicator consists of a calibrated crystal type microphone, an a-f. amplifier with all-metal tubes, a calibrated attenuator, an ear weighing network, a decibel meter and a crystal type headset. Range 30-90 db. A.S.A. standard. For a-c. operation, but batteries may be used.—*Industrial Apparatus Co., 720 N. Wabash Ave., Chicago, Ill.*

Metal-tube Form Resistor

Employing a standard metal-tube casing and 8-prong octal base, new "Series MT" line voltage dropping resistor has the size, shape and finish of metal-tube 25Z6 rectifier and 25A6 power tube, and is installed by providing another octal socket. It meets Underwriters' requirements regarding "hot" terminals and high leakage resistance to ground keeps the dissipated heat above chassis, and minimizes fire hazard. Available in any total voltage drop and for practically all pilot-lamp and tube combinations. Ballast action in pilot-lamp resistor section can be provided. Coded and wired in accordance with proposed R.M.A. standards covering such devices. Three standard types cover pilot-lamp and filament requirements of 4-, 5- and 6-tube sets, dropping the voltage from a 117-volt line; special types for other line voltage and filament loads.—*Clarostat Mfg. Co., Inc., 285 N. 6th St., Brooklyn, N. Y.*

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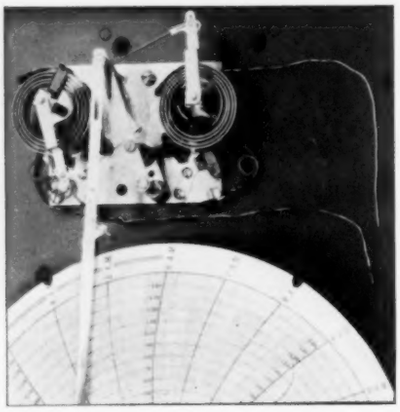
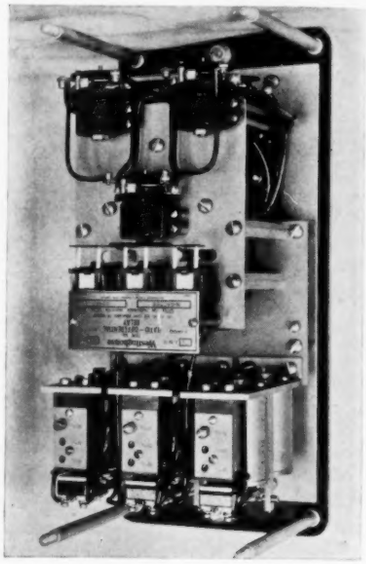
To minimize tubing error and pressure-spring error it has been necessary, with usual uncompensated construction of gas-filled systems, to specify relatively large bulbs—especially for tubing lengths >25 ft.—bulb size increasing with both tubing length and accuracy requirements. A new recording thermometer, announced in 8″



and 12″ chart sizes, embodies a method of compensating for tubing and head temperature fluctuations which permits (1) shorter ranges, (2) longer tubing and (3) smaller bulbs. Method consists of having penarm acted upon in opposite senses by two thermal systems which are identical except that only one capillary communicates with the bulb, the other (enclosed in same tubing) being closed at the bulb end. Effects of temperature variations along tubing and at instrument thus cause the two thermal systems to oppose each other, and only effects of temperature changes at bulb produce motions of penarm, the scale law being linear. New recorder is available in various ranges between −60°F. and 1000°F., with tubing lengths <100 ft. (longer under certain conditions) and relatively small bulbs. The 12″ size may be had in a two-pen model.—*The Bristol Co., Waterbury, Conn.*

Ratio Differential Relay

Type HA Ratio Differential Relay is designed to increase system stability limits by placing the protection of generators and transformers on the same high-sped basis now widely set for transmission lines. It has an operating time of one cycle and reduces considerably the chances of damage which might occur to equipment protected by slower speed relays. Two types are available, one for generator and motor protection and the other for transformers. Because their operating current varies in proportion to the load, faulty tripping is prevented and the relays may be set for close protection at normal loads. They have extremely low burden which is important in connection with low-capacity current transformers. Simple balance beam construction is employed with the restraining and operating units being magnetically identical. The generator relay can be set to operate in one cycle on internal troubles with current as low as 5% of the smaller secondary current without danger of tripping on heavy overloads or on external faults. It is provided with taps so that it may be set to operate on an unbalance equal to 5, 10, or 20% of the smaller secondary current. This relay measures 5½″ square. The transformer relay (illustrated) is suitable for the protection of two-wind-



ing transformers. It is equipped with taps so that current balancing transformers are unnecessary and is designed to operate on a fixed percentage differential of 25%. Operation on transformer magnetizing current inrushes is prevented by a tripping suppressor without sacrificing any operating characteristics. This relay measures 5½″ × 12″.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

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(U.S.A. Patents)

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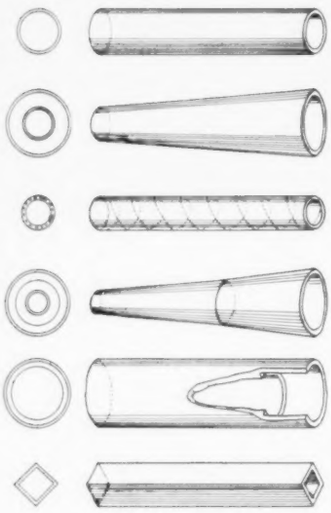

Smallest bore 0.5 mm.—Largest bore 50 mm.

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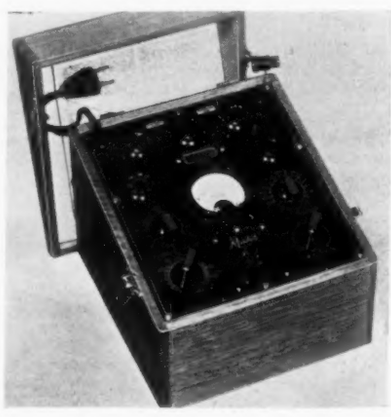
Tube Tester

Improved 1936 "Model 430" tube tester is for checking all glass, metal and metal-glass tubes for value and shorts under actual load conditions. Feature is a sha-



dow type a-c. indicator for line voltage adjustment. Beside indicating actual line voltage setting, it also shows when left connected to line supply when not in use. Model 430 has five sockets for receiving every type of tube, contains a direct-reading "Triplett 221 meter" with good-bad scale. Testing requires four operations. Removable cover makes tester equally suitable for counter or portable use.—*The Readrite Meter Works, Bluffton, Ohio.*

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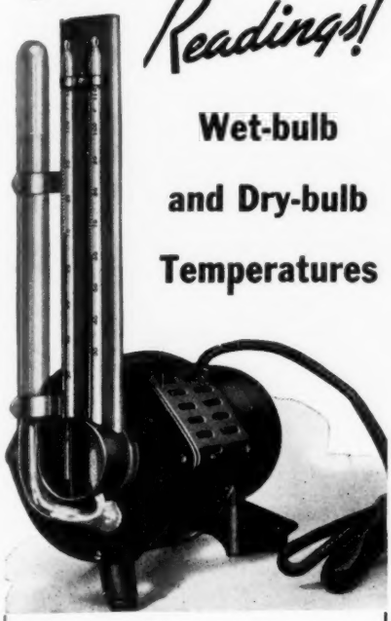

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● Bulletin H-302 describes this interesting device and includes a Table of Relative Humidities from 50 to 198 degrees, dry-bulb . . . Johnson offers also a superior Sling Psychrometer, Bulletin H-303, and a direct-reading Relative Humidity Indicator, Bulletin H-301.

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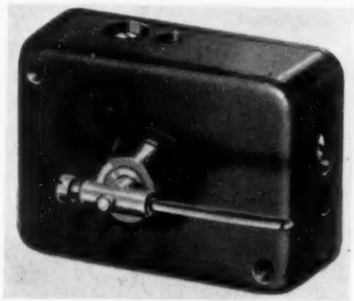
High-speed Micro Switch

Half an inch-ounce of energy operates this new smaller model (see *Instruments*, Jan. 1934, page 16). Illustration shows actual size of "Type ES-9": $1\frac{5}{8}$" × $1\frac{1}{8}$" × $\frac{5}{8}$". Weight is 1 oz. Consists of Bakelite case and six parts including phosphor-bronze spring, coin silver contacts and bronze shaft bearing. Has been tested



at 1800 operations per minute for 15,000,000 operations, at end of which there was negligible wear and no change in spring tension or operational characteristics. Supplied for right- or left-hand operation, for reciprocal or rotary motion, open or closed circuit. Make and break positions may be adjusted if desired. Suited to operation of electric counters and recorders, for signaling, as a limit switch, for controlling motor operation, for lighting and other electrical circuits, etc.—*Production Instrument Co., 1325 South Wabash Ave., Chicago, Ill.*

Halide Leak Detector

Growing use as refrigerants of non-combustible halide gases which are relatively odorless, tasteless, and colorless created need for quick and sure method of locating leaks while cooling units are being installed and later during servicing. The Prest-O-Lite Halide Leak Detector has been developed for this purpose. Its makers point out that certain halide derivative gases used as refrigerants are combustible, and that before using any device, nature and property of halide gas used should be ascertained if not definitely known. New device consists of a regular Prest-O-Lite needle valve torch handle assembly, a burner which includes a suction nipple for attaching a rubber hose, and a chimney with a copper reaction plate. Rapid flow of acetylene through burner draws in any refrigerant gas near open end of suction tube, which is used to explore around those places where a leak might occur. Visible color indication of small concentration of refrigerant gas is given by a green-tinted flame; when a relatively large amount is present, flame assumes an intense violet color; after source of leak has been passed, flame clears almost instantly. If surrounding atmosphere contains a considerable amount of refrigerant gas, leak can be located by variation in intensity of flame color. —*The Linde Air Products Co., 30 E. 42nd St., New York City.*

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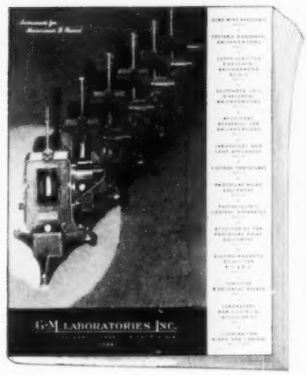

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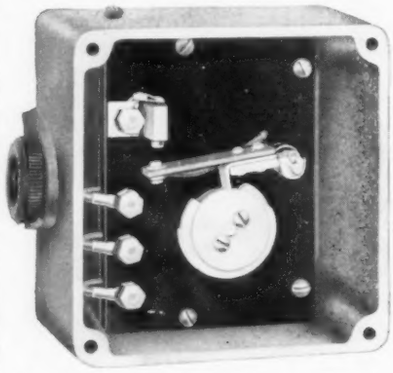
Motor-operated Timer

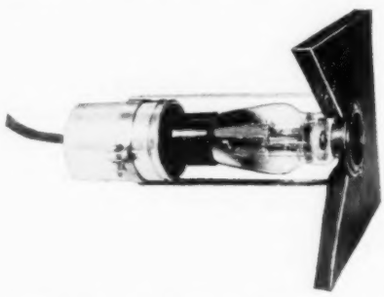
New "Jewel No. 11," (first synchronous-motor-powered timer in the Walser line, all previous models having been spring or non-synchronous motor types) may be adapted to any time sequence of open and closed circuits over time cycles of seconds, minutes or hours. Two or more adjustable cams, mounted on a



drum, are rotated by the self-starting motor through reduction gears to obtain the time cycle required. Frequency of contact is a product of speed per revolution and number of cams on drum. Cams are adjusted to obtain varying ratios of closed and open circuits within fixed limit of time cycle: one extreme being 95% on and 5% off, the other being 95% off and 5% on. Two types of switch action are provided depending upon rotating sped of cam shaft. On high-speed timers where maximum time cycle is <4 min., silver contacts are actuated by a single-action mechanism; at lower speeds a double-action switch mechanism provides quick make and quick break. Motor is lubricated by a supply of sealed-in oil. Motor and switch connections and switch contacts are attached to a Bakelite panel which covers a cast chassis to which motor and gear train are attached. Entire unit is enclosed in a metal housing.—*Walser Automatic Timer Co., 420 Lexington Ave., New York City.*

Electron-Eye Tuning

Known as the Taco Tuning Indicator, this self-contained unit makes use of the 6E5 tube, obtains its power supply from the radio set itself, and is installed



by cutting or drilling a hole in the set panel for the "window" through which the tube target is viewed, and mounting the bracket behind the panel. In the latest model Taco Tuning Indicator, a spcial filter disk or "intensifier screen" placed before the 6E5 tube augments the contrast between luminous ring and dark segment.—*Technical Appliance Corp., 17 E. 16th St., New York City.*

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Temperature Control with Regard to Oscillations of External Conditions and to Characteristics of Walls

By EMERSON M. PUGH

Associate Professor of Physics, Carnegie Institute of Technology, Pittsburgh, Pa.

NOT long ago, a Milwaukee company built a movie theater and made the southern wall extra thick because it was exposed to the sun all day. Too late they discovered that this thick wall retarded the heat wave so that the peak arrived in the building in the early evening when the theatre was crowded. Since there was no afternoon show, a thin wall of sheet iron would have been more effective.

In the design and application of cooling systems, the nature of heat flow into a building needs detailed consideration. While the average flow of heat through a wall can be calculated in the usual manner from the average internal and external temperatures, it should be pointed out that this average flow is not the significant quantity. What the engineer needs to know is the maximum heat flow—which cannot be calculated so simply.

The heat flow due to the sun effect through different types of roof panels has been measured[1] by the Research Laboratory of the American Society of Heating and Ventilating Engineers in Pittsburgh. My mathematical solution of the problem, amply verified by these experiments, was published in two journals[1, 2] and inasmuch as this solution seemed too complex for the average engineer to use, a simpler approximate solution was also given in these articles. However, the approximate solution was still so complex that most engineers continued to use rule-of-thumb methods found in the handbooks, even though these methods might lead to the kind of difficulties experienced by the Milwaukee concern. Fortunately, since this material was published, it has been found possible to reduce the accurate solution to a series of curves (herewith published) so that practical

SPECIFICALLY, this article deals only with one problem in one field of temperature control. Dr. Pugh's solution, however, is *complete;* and as presented here it permits heretofore unattained certainty and accuracy. Moreover, it is of such immediate practical usefulness and it marks such a considerable advance in rational method that it represents an important contribution to the *general* field of temperature control. Readers who have to do with industrial processes will see the point of the theater story: it bears a close analogy to many misbehaving furnaces, stills, ovens, towers, and other temperature applications.—MFB

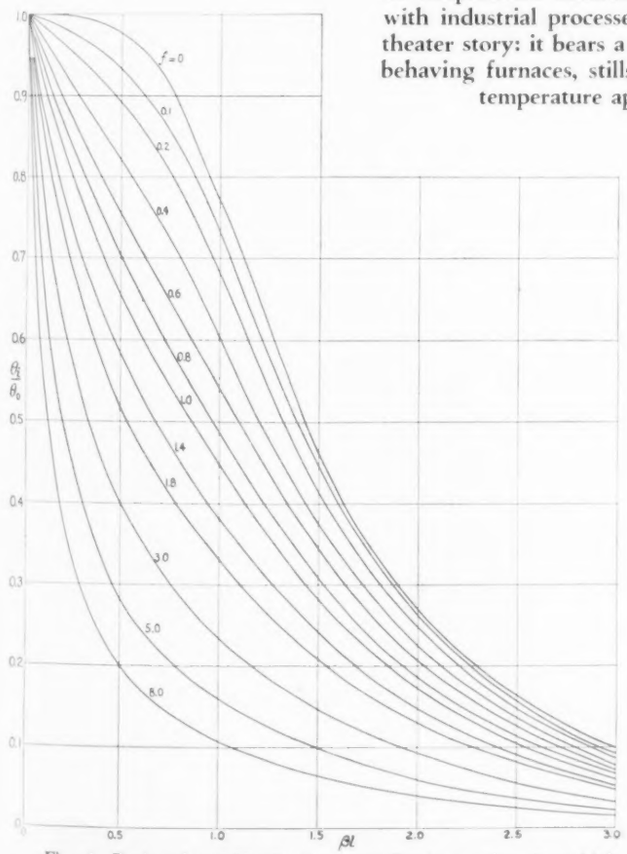


Fig. 1. Ratio of amplitude θ_1 to amplitude θ_0, for sinusoidal temperature variations.

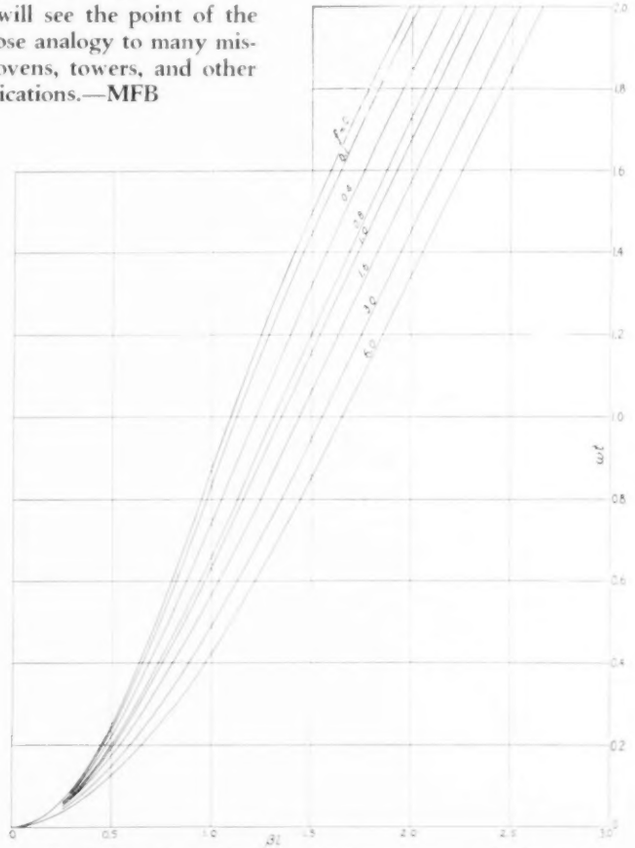


Fig. 2. Time lag t_0 for sinusoidal temperature variations. $\omega = 2\pi/T$, where T is the period.

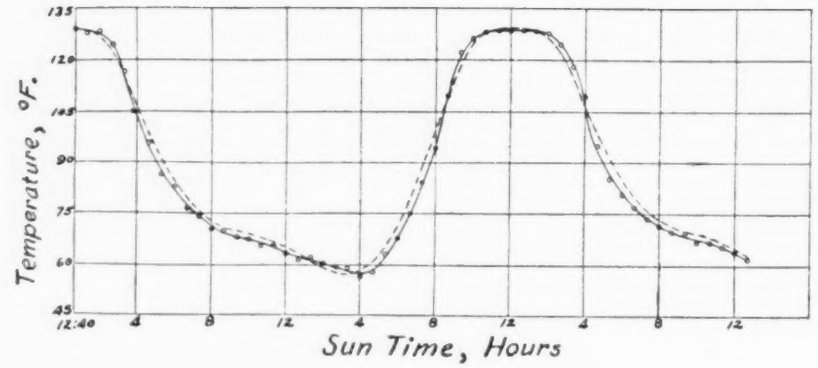


Fig. 3. Typical curve of the variation with time of the temperature of the surface of roof panels exposed to the summer sun. Dotted line shows the sum of two sine curves whose frequencies are in the ratio of 1 to 2 and whose amplitudes are in the ratio of 1 to 0.32, respectively.

problems can now be solved with little difficulty.

We can divide the total heat flow through a wall or roof, into two components: one steady, which is that usually calculated; the other periodic, requiring special treatment. Over a 24-hr. period, the average heat flow into a building due to the periodic component is zero. The conventional calculation, therefore, does give the correct average heat load. However, in the design of cooling equipment, the peak of the heat flow is the important factor and this may be several times the average value. It is possible to design a wall so that the cooling portion of the heat wave coincides with the peak of the heat load from other sources, thus reducing the cooling requirements.

If the periodic temperature component of the outside wall surface is assumed to be $\theta = \theta_o \cos \omega t$, then the periodic temperature component of the inside wall surface is given by

$$\theta = \theta_o [\, De^{-\beta l} \cos (\omega t + \alpha - \beta l) + Ee^{-\beta l} \cos (\omega t + \delta - \beta l)\,], \quad (1)$$

where l is the wall thickness. The constants D, E, β, α and δ depend upon the physical properties of the wall (conductivity K, density ρ, specific heat c, inner film conductance ε) and the period $P = 2\pi/\omega$. Eq. (1) may be written

$$\theta = \theta_i \cos \omega (t - t_o), \quad (2)$$

where θ_i and t_o are complex functions of D, E, β, α, δ, l, ω and θ_o. If a new constant f $(= \varepsilon / K\beta)$ is introduced, θ_i / θ_o and t_o can be expressed in terms of the two dimensionless quantities f and βl, where $\beta = (c\rho\, \omega / 2K)^{\frac{1}{2}}$. It will be noticed that θ_i / θ_o is the ratio of the amplitudes of the internal and external temperatures and t_o is the time lag of the maximum internal temperature behind the maximum external temperature. In Fig. 1 θ_i / θ_o has been plotted for various values of f and βl. Thus, if the amplitude θ_o of the outside temperature and the constants f and βl of our particular wall are known, we can find θ_i directly from the curve. The maximum heat flow is then $\varepsilon\theta_i$ plus the average heat flow calculated in the usual manner. The time of arrival of this maximum heat flow can be obtained from Fig. 2 which gives the lag of the inside maximum temperature behind that of the outside maximum temperature. In order that the curve may be useful for all possible frequencies of the impressed heat wave, ωt_o has been plotted instead of the time lag t_o. $\omega = 2\pi/T$, where T is the period.

Figs. 1 and 2 give all the information needed for sinusoidal temperatures, but the sun does not produce simple sinusoidal temperatures on walls or roofs. The actual temperatures follow complex curves with periods of 24 hrs. These curves can be analyzed into their sinusoidal components which must be treated separately, since the values of f and βl will be different for each component. The experiments of the Research Bureau under F. C. Houghton[1] showed that for practical purposes the temperatures of surfaces exposed to the sun can be expressed by a Fourier series with only two periodic terms, the fundamental and the first harmonic (double frequency term). The analysis of the experimental curves[1] shows them to be surprisingly similar even when they were taken at different times of the year. In particular, the percentage of the first harmonic required to fit the curves of external temperatures is quite constant and averages 32% of the fundamental. Also if the peak of the fundamental is made to lead the peak of the first harmonic by 45 minutes (time) the resulting composite curve represents the typical experimental curves. See Fig. 3.

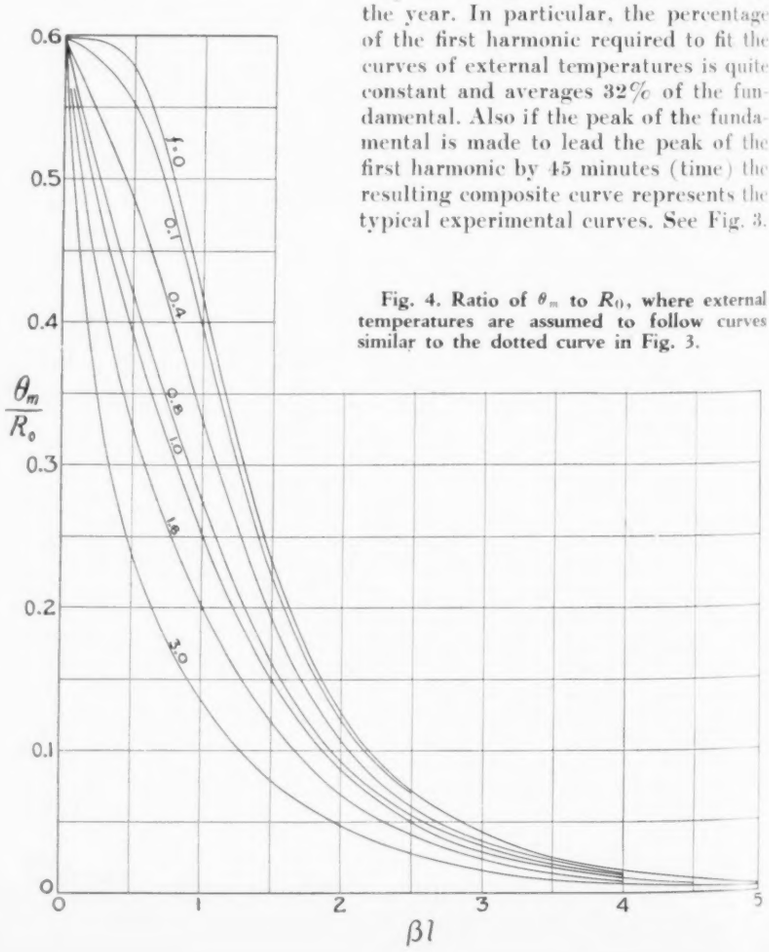
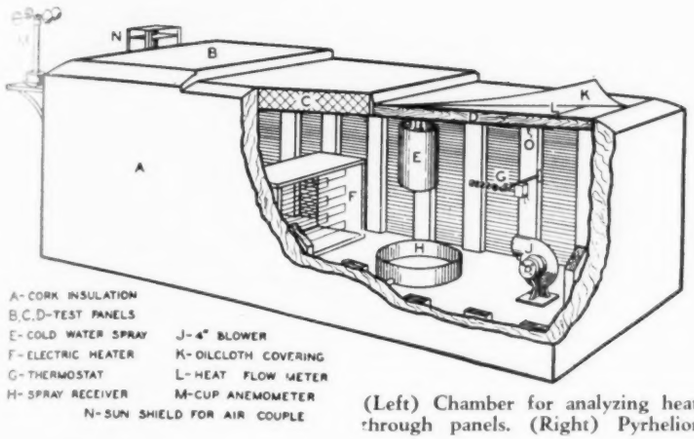
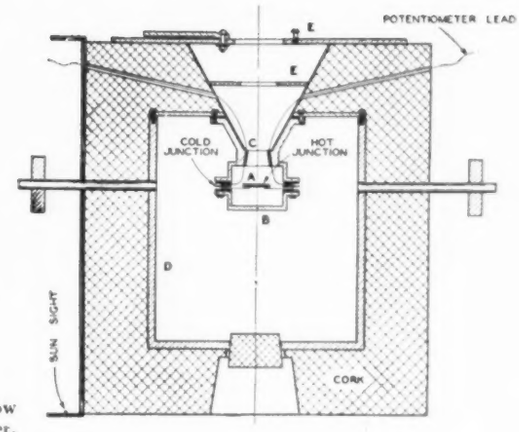


Fig. 4. Ratio of θ_m to R_0, where external temperatures are assumed to follow curves similar to the dotted curve in Fig. 3.





(Left) Chamber for analyzing heat flow through panels. (Right) Pyrheliometer.

If we assume that the composite curve is the typical external temperature curve for the sun effect, we find that we can express everything in terms of the f and βl of the fundamental and the range of the external temperatures R_0. To calculate the maximum flow of heat we need the maximum of the periodic temperature component of the inside surface θ_m. The maximum heat flow is given by $\varepsilon\theta_m$ added to the average heat flow. Fig. 4 shows the ratio of θ_m to R_0 plotted as functions of f and βl. Fig. 5 shows the time lag of θ_m behind the external peak temperature. Table I gives values of the constants for some of the roof panels tested by the Research Bureau.[1] Let us use the 4" gypsum panel as a simple example to show how the curves are used for calculation. Table I $f = 3.99$ and $\beta l = 1.38$. The value of θ_m / R_0 corresponding to these values of f and βl is found from Fig. 4 to be 0.08. Let us assume that the temperature range on the outside surface is $(132 - 60 =)$ 72° F., the same as occurred on this panel during the test on September 10, 1931 (Fig. 6). Since the value of ε for this slab is 1.9, the maximum heat flow due to the periodic component is $1.9 \times 0.08 \times 72 = 11$ B.t.u./ft.²/hr. The heat flow due to the steady component calculated in the usual manner is 6.5 B.t.u./ft.²/hr. Then the maximum heat flow due to both components is 17.5 B.t.u./ft.²/hr., which is 2.7 times the steady component usually calculated, and which agrees well with the experimental results shown in Fig. 6. From the curves in Fig. 5 we find the time lag of the maximum heat flow behind the temperature maximum on the outside surface to be 2.8 hrs. which also agrees with the experimental results shown in Fig. 6. It is interesting to notice that the 8" cork-iron panel ($f = 1.65$ and $\beta l = 5.1$) has a time lag of 18.5 hrs.

TABLE I. Physical properties of some panels tested by the Research Bureau of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa.

DESCRIPTION OF PANEL	THICKNESS IN INCHES l	CONDUCTIVITY κ	DENSITY ρ	SPECIFIC HEAT c	INNER FILM CONDUCTANCE ε	$\beta = .04\sqrt{\frac{\varepsilon c}{\kappa}}$	βl	$f = \frac{1}{\kappa\beta}$
2" LAMINATED IRON & CORK	2.67	.427	61.68	.192	1.0	.550	1.47	4.25
4" LAMINATED IRON & CORK	4.47	.734	238.8	.128	1.25	.675	3.02	2.53
8" LAMINATED IRON & CORK	8.32	1.231	357.0	.119	1.25	.614	5.10	1.65
2" PINE	2.16	.830	37.5	.467	1.9	.480	1.04	4.59
6" CONCRETE	6.19	8.00	148.6	.230	1.9	.216	1.34	1.10
4" GYPSUM	4.19	1.445	64.9	.234	1.9	.329	1.38	3.99

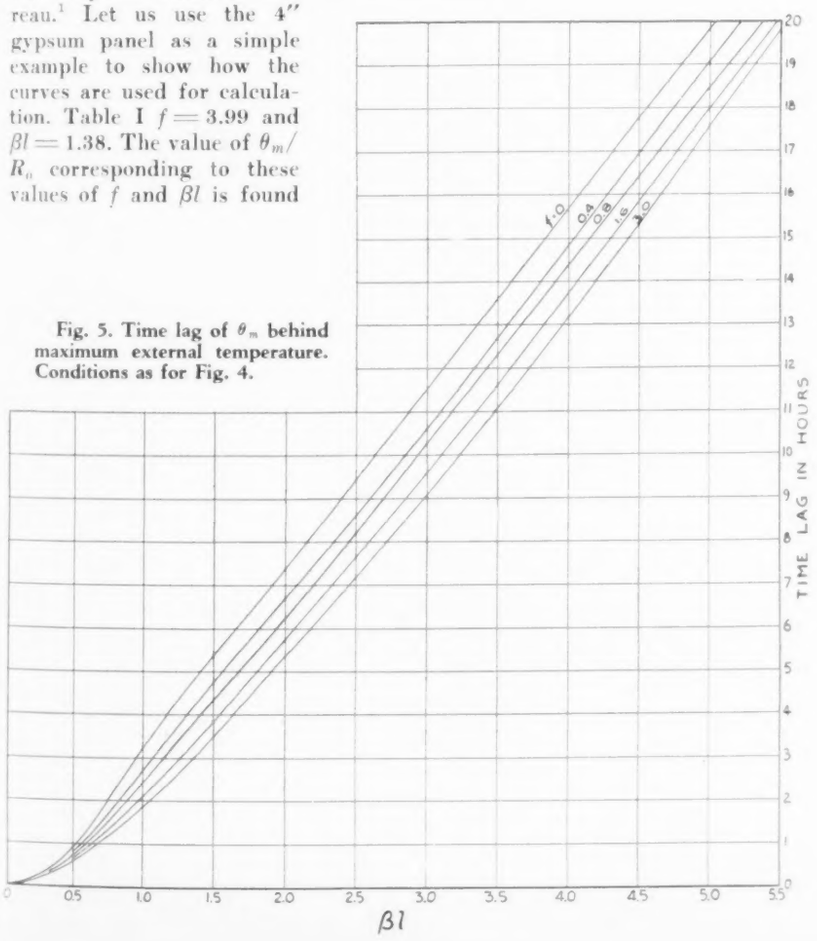


Fig. 5. Time lag of θ_m behind maximum external temperature. Conditions as for Fig. 4.

While the equations given for the constants f and βl hold in any consistent system of units, they must be modified for the British Engineering system which mixes feet and inches in its physical constants. When K is in B.t.u. inch/ft.²·hr.·F°, ρ is in lbs./ft.³, ε is in B.t.u. ft.²·hr.·F°,

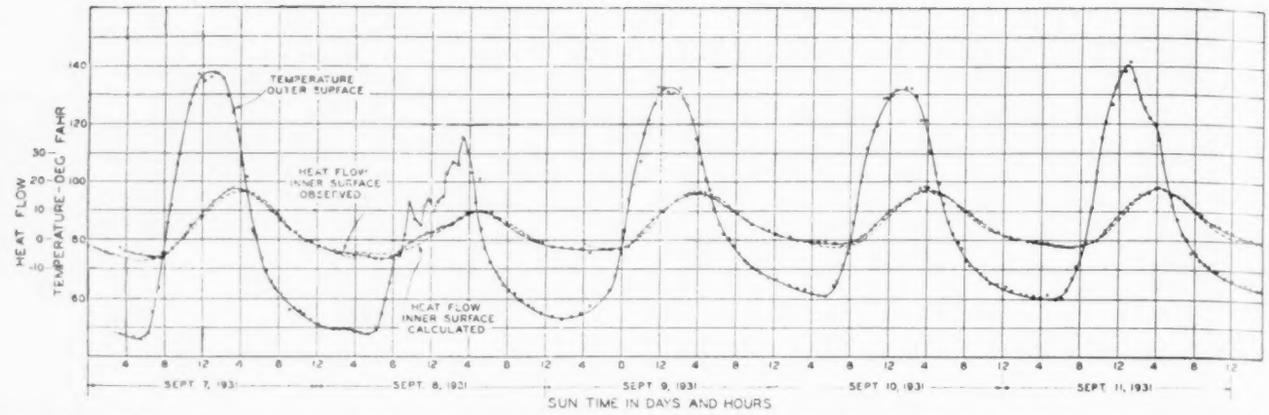


Fig. 6. Curves for 4″ gypsum panel showing outer surface temperature and heat flow through the inner surface as observed and calculated.

and l is in inches; the constants become $\beta = [(\pi/288)(c\rho/K)]^{\frac{1}{2}} = 0.1044\ (c\rho/K)^{\frac{1}{2}}$ and $f = \varepsilon/K\beta$ for a fundamental period of 24 hrs.

It must be remembered that while the curves of Figs. 1 and 2 are exact calculations, the curves in Figs. 4 and 5 are based upon experiments performed in Pittsburgh on roof panels. It is not known, therefore, how closely the last two curves apply to roofs in other latitudes or to side walls anywhere. Nevertheless, it is believed that if these curves of Figs. 4 and 5 are used on any wall or roof in the temperate zones the results will be better than can be obtained from present handbook methods. Wherever the sun effect is important, the surface temperatures must follow curves somewhat similar to Fig. 3, with a high peak in the daytime and a flat cooling curve at night.

When a wall contains many windows, the direct rays of the sun may heat up the interior so that the heat wave through the wall may be largely masked. The wave exists, however, and has an additive effect.

It is possible to extend this work to give solutions for compound panels made up of slabs of different materials. The time required for preparing curves for this purpose has not yet been available.

I wish to acknowledge my indebtedness to the many who have aided me in this work. I am particularly indebted to Messrs. F. O. Mortlock, I. Gazdik, and J. J. Dyke. Mr. Mortlock and Mr. Gazdik performed many of the calculations and Mr. Dyke performed them all independently.

[1]Houghton, Blackshaw, Pugh and McDermott. Heat Transmission as Influenced by Heat Capacity and Solar Radiation, *Transactions Am. Soc. Heating and Ventilating Engineers*, Vol. 38, 1932, pages 231-254.
[2]Pugh and Houghton. Heat Waves through Insulating Walls, *Physics*, Vol. 2, 1932, pages 93-98.

INSTRUMENTS' BOOK SHELF

Oscillators. Volume III, Rückkoplung (Feed-back), of the three-volume **Lehrbuch Der Elektronen-Röhren,** by H. Barkhausen. Verlag von S. Hirzel, Leipzig, 1935. Paper, 6x9 inches, 174 pages. Price 7rm.

English-language writers on oscillators generally gloss over the subject with a few bland generalities or they plunge at the outset into a morass of differential equations and become bogged in a welter of involved mathematics. There is nothing in Dr. Barkhausen's volume not already known about oscillators; but he conveys a physical picture making so clear and understandable the working of an oscillator that it deserves the highest commendation.

It is Dr. Barkhausen's method to set up, as criterion of a device, a simple equation summarizing all its fundamental characteristics. Then in the light of this equation he analyzes every form of that device. For oscillators, to accomplish this, he considers the oscillator an amplifier in which output energy is fed back to the input. How much of the output must be fed back to the input for a given oscillation to sustain itself? This question is the basis on which a simple equation is developed involving all the factors basic to the operation of an oscillator. This leads to a simple formula called a "feed-back coefficient" for evaluating the operation of an oscillator in terms of the circuit constants and tube parameters. By a nice device of equivalent-circuit conversion (the "three-point network") the many complicated oscillators are reduced to one simple circuit readily investigated by this simple equation. Through this means the analysis is extended to treat all the many forms of oscillators in use, establishing their fundamental requirements for: (1) setting-in of oscillations; (2) stability of amplitude; (3) frequency stability.

All other types of oscillators beside feed-back—relaxation oscillators, electronic-coupling (dynatron) and electronic (Barkhausen-Kurz, magnetron) oscillators—also come in for a physical picture both clear and illuminating. Merely to list the chapter headings will illustrate how thoroughgoing, methodical and complete is the treatment of the whole subject of oscillators in this book.

I. The Principle of Self-excitation. II. The Self-excitation Formula. III. Deductions from the Self-excitation formula. IV. Inductive Feed-back. V. Potential-Divider (Three-point Circuit) Feed-back. VI. The Amplitude of Self-excited Oscillations and their Stability. VII. The Frequency of Self-excited Oscillations and their Stability. VIII. Feed-back Oscillators for Short-waves. IX. Descending Characteristics (Electronic-coupling "Dynatron" Oscillators). X. Self-excitation without Tuned Circuits (Relaxation Oscillators). XI. Electron-flight (Barkhausen-Kurz, Magnetron) Oscillators. XII. Summary.

There follows a second part of the book on "undamping" (entdämpfung) or "regeneration" as it is known in American texts. It is a complete study of what occurs in various vacuum-tube circuits when feed-back is present, but not enough to cause oscillation. Here as for the oscillators, the physical picture of these phenomena is excellent.

Two lacks stand out as prominent faults in the book because of its thoroughgoing completeness in other respects: the lack of a good list of references, and the absence of any quantitative treatment of oscillator design. The paucity of references, beside hindering further study, is all the more a loss, because some of the basic papers on oscillators are exhaustive treatises on one aspect of the oscillator or another, and greatly enhance one's thinking powers in the whole field. For instance there is the paper by C. K. Jen (*Proceedings Inst't. of Radio Engineers*, Vol. 19, Dec. 1931, pages 2109-2144) which takes up the question of magnitude and phase of feed-back needed to produce oscillations from a viewpoint exactly such as that underlying this volume, and gives complete experimental data on its application to all forms of oscillators. Or there is the paper by Chaffee on "Regeneration in Coupled Circuits" (*Proceedings Instit. of Radio Engineers*, Vol. 12, June 1924, pages 299-361) which investigates regeneration in all its ramifications.

The other deficiency is the want of a quantitative treatment of an oscillator design. True, exact engineering of an oscillator has been a moot subject for a long time, and has only recently been fully solved. (See forthcoming paper, A Method of Determining the Operation Characteristics of a Power Oscillator, by E. L. Chaffee and C. N. Kimball, *Journal of the Franklin Institute*, Vol. 221, Feb. 1936.) But the work leading up to this point has been accumulating in a steady stream of papers on oscillator design. Hence in a monogram on oscillators a worthwhile treatment on oscillator calculation could well have been given.

Altogether, Dr. Barkhausen has a happy faculty of presentation which makes this volume almost a classic in technical literature. It is a pity that there is not a good translation of it in English. However, those willing to go through the author's Vol. I which is in simple German and explains the terms used throughout the three volumes will find this treatise on oscillators quite easy to read.

—H. Olken (5.4) -B-

Industrial Applications of X-ray Diffraction Analysis

By VICTOR HICKS

The Coöperative X-ray Laboratory,* University of Pittsburgh

SOON after the discovery of X-rays, it was recognized that they afforded an important industrial, as well as medical, tool for seeing through opaque objects. Some industrial applications of this tool—radiography—were made immediately[1]. The development of high-voltage X-ray tubes permitted the extension of these applications. Today X-ray radiography constitutes an important part of the physical testing of welded pressure vessels. In the foundry, it offers an aid for the development of casting procedure. Inspection of assembled products for imperfections or foreign objects may be made occasionally; with some slight modificaton of the radiographic procedure, examinations may be visually made of each completed object. These applications have made this tool increasingly known in some industries.

Later applications of the physical properties of X-rays have led to the development of another industrial tool of equal importance, which may be described as a tool for seeing small things. The operation of the second tool—X-ray diffraction analysis—is the subject of this article.

PHYSICAL PRINCIPLES OF THE TOOL FOR SEEING SMALL THINGS

Physical studies have shown that the atoms of most substances are spherical, or approximately so. A solid object may be thought of as composed of atoms packed together as though they were small rubber balls of different sizes. (The way in which the atoms of some typical substances pack together in the solid form is illustrated by Fig. 3 but for the present purposes the details of the arrangements are not important.) The physical basis, on which the tool for seeing small things rests, is *regularity of structure*, which may extend over thousands to millions or more atoms in one solid body. In consequence of this regularity the atoms lie in uniformly spaced parallel planes. In the model of rock salt, for example, planes which contain only sodium atoms may be readily selected, and parallel to these planes are found others which contain only chlorine atoms; others contain both types of atoms, such as the planes through the diagonals of the square faces. These planes are in the neighborhood of one two-hundred millionth of an inch apart. X-rays can be reflected from these planes just as light is reflected from a silvered surface, but there is one aspect in which the reflection differs. Because of the penetration of X-rays into solids, reflections take place not only from one plane, but from large numbers of parallel planes. It follows that X-rays cannot be reflected from the atomic planes in all directions, as can light from a mirror, but reflections occur only when the beam strikes these planes at certain sharply defined angles, which depend, among other things, upon the distance between the planes and the wave-length of the X-rays employed. It is only necessary, therefore, to *measure the angles* at which X-rays of known wave-length may be reflected in order to determine the distance between the atomic planes, and thus to learn something, at least, of the atomic arrangements of various materials.

A convenient method by which the reflections (or more strictly, the diffractions) of X-rays at angles of incidence from approximately zero to 90° on atomic planes are recorded simultaneously on a photographic film is known as the Debye-Scherrer-Hull method. The X-ray beam is confined to a small bundle of about

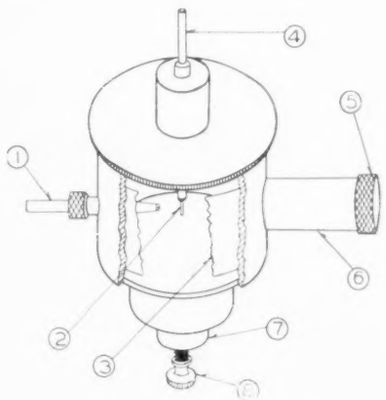


Fig. 1. A Debye-Scherrer X-ray diffraction camera. (1) aperture tube; (2) specimen; (3) X-ray film; (4) specimen holder; (5) cap with fluorescent screen; (6) exit tube for primary X-ray beam; (7) sliding rod for adjustment of camera in X-ray beam; (8) for clamping camera to X-ray tube.

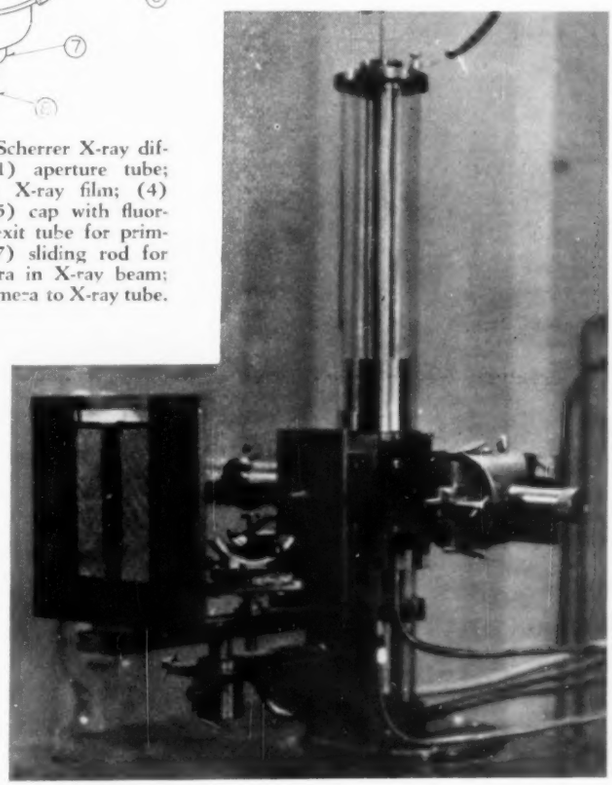


Fig. 2. X-ray tube with (at right) cylindrical powder camera and (at left) fiber diagram camera.

This article constitutes an amplification of the second half of a discussion presented at the Conference on Industrial Physics held at the University of Pittsburgh on November 15, 1935. The original discussion, dealing also with radiography but more briefly with X-ray diffraction, appeared in the March issue of *Physics*, pages 79-84.

*The Coöperative X-ray Laboratory is sponsored jointly by the Departments of Physics and of Chemistry and Mellon Institute of Industrial Research at the University of Pittsburgh.

[1] A. Sauveur. Early Experiments with X-rays. *Metals & Alloys*, Vol. 3, 1932, page 82. Reproduction of clipping from *Chicago Times-Herald* of February 19, 1896.

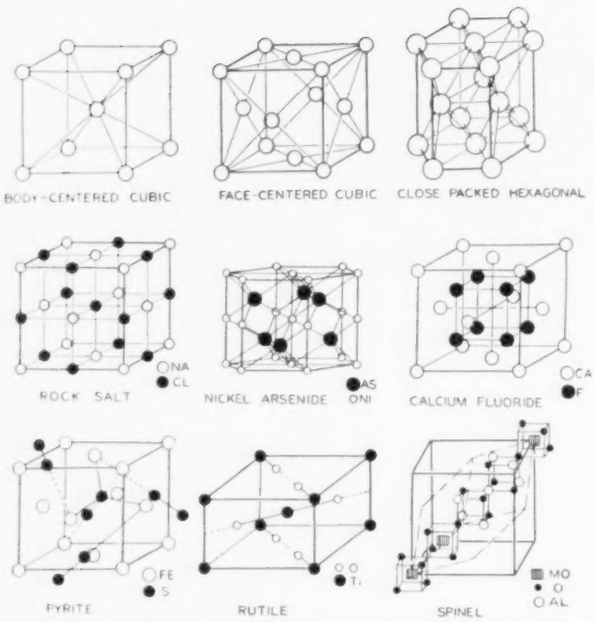


Fig. 3. Some of the more common types of crystal lattices.

1/16" diameter by a system of circular apertures. The material to be investigated is powdered and formed, with a suitable binder such as collodion, into a compact rod of about 1/32" diameter and about 1/4" long; metals may be turned or drawn into such rods, and fibers may be wrapped into compact bundles. The specimen thus prepared is placed with its axis perpendicular to the X-ray beam. A double-coated photographic film is bent into a cylinder coaxial with the specimen. The assembled apparatus for holding the system of apertures, the specimen, and the film, is known as an X-ray camera. See Figs. 1 and 2. X-rays of rather low penetrating power are commonly used, and the X-ray tube generally has a thin window of glass or aluminum to allow the X-ray beam free exit. Descriptions and photographs of such cameras and X-ray tubes have been given earlier in this journal by H. R. Isenburger[2]; a more detailed description of the Debye-Scherrer-Hull method and the principles on which it rests may be found elsewhere[3]. The film, when finished, is known as a diffraction pattern or photogram. A change in the positions of the reflections without a change in the relative configuration of the diffraction pattern indicates an alteration in only the dimensions of the structure, the general arrangement being preserved. The appearance of a new configuration of reflections indicates a new arrangement of atoms, and thus, usually, gives evidence of a new substance.

SOME APPLICATIONS OF THE TOOL FOR SEEING SMALL THINGS

1. *Metallurgy.* An example of the application of this method to the silver-cadmium alloy system by Astrand and Westgren[4] will serve to illustrate the explanation just given. The phase diagram (upper part of Fig. 4) is characterized by a large field of solid solution of cadmium in silver, a narrow field of a second phase which overlaps two others, a third and a fourth phase both of which have a range of solid solubility for cadmium of some extent, and finally a solid solution of silver in cadmium. The spatial arrangements of the atoms deduced from diffraction patterns of these alloys are shown below the phase diagram in Fig. 4. Over the first large range of solid solution, the original arrangements of the silver atoms is maintained, cadmium atoms being substituted at random for the silver atoms, with a resulting expansion of the atomic arrangement. In the second phase, the cadmium atoms have definite positions with respect to the silver atoms, and the binary compound AgCd is indicated. The third phase has a large, complicated structure requiring 52 atoms to represent a single structural unit, and foreign atoms can find room in it with only a small change in the arrangement. In the ideal case this structure represents an intermetallic compound of the formula Ag_5Cd_8. The fourth phase is similar in structure to the last one, cadmium. The structure of the fourth phase, in the ideal case, also represents a compound which has the formula $AgCd_3$. The large structural unit of the third phase is similar to that of γ brass, and, in fact, this discussion applies just as well to the copper-zinc alloy system in so far as the general results are concerned.

Such studies as this allow one to determine the type of solid solution, that is, to distinguish between the cases in which the solute atoms substitute for the solvent atoms and those in which the solute atoms slip in between the solvent atoms. It also permits the determination of the range of solid solution. Further, it gives positive proof of the existence of intermetallic compounds.

Important as these contributions are, however, this method still has one greater advantage, for it makes possible a classification of alloy systems on a new basis. The binary alloys of copper, silver, or gold with aluminum, zinc, cadmium, or tin have one or more phases, the structures of which are similar to those of the silver-cadmium system; other systems also fall into this classification. When the initial components have similar structures, they are generally miscible in the solid state in all proportions, but if the structures are different, they are

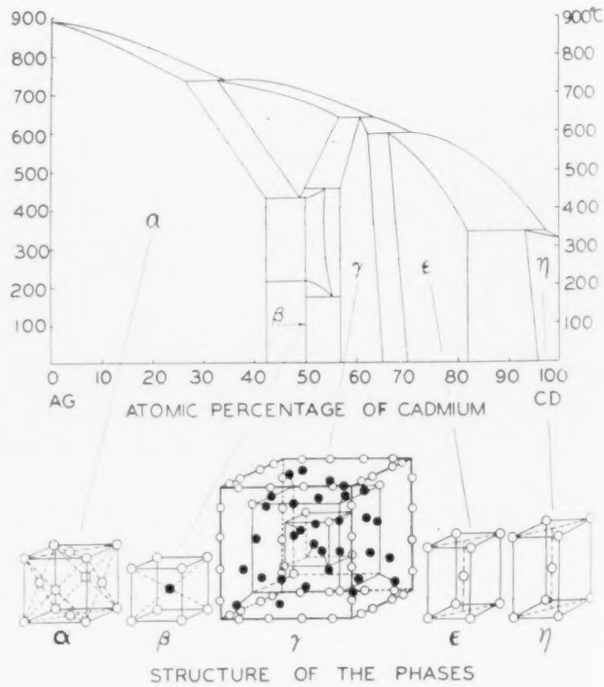


Fig. 4. The silver-cadmium alloy system.

[2]H. R. Isenburger, Recent X-ray Diffraction Progress, *Instruments*, Vol. 8, Nov. 1935, pages 302-303. Gives also a list of 10 recent publications.

[3]George L. Clark, Applied X-rays, Second edition, McGraw-Hill Book Company, New York, 1932. See page 199.

[4]H. Astrand and A. Westgren, *Zeitschrift für anorganische und allgemeine Chemie*, Vol. 175, 1928, pages 90-96.

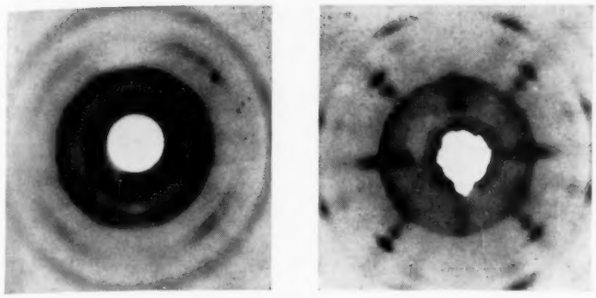


Fig. 5. Diffraction patterns of rolled steel sheets: (A) low reduction; (B) high reduction.

miscible, without the formation of compounds or simple mixtures, over only a limited range. It is the atomic arrangements of the phases, of course, which determine the physical properties of the alloys. On the basis of information now available, it is possible, in many cases, to predict the atomic arrangement and the type of phase diagram to be expected from a knowledge of the elements forming the alloy, and thus to determine in advance some indication of the physical properties of a new alloy.

X-ray diffraction methods give information concerning the processes of rolling and drawing. It has been found that there is a close relation between the alignment or orientation of the crystallites produced in a metal by such processes and the resultant mechanical and magnetic properties. X-ray diffraction methods permit the measurement of the degree of crystallite orientation. Fig. 5A shows a diffraction pattern of an iron sheet with a small amount of reduction in thickness produced by cold-rolling; the pattern is characterized by nearly continuous rings which indicate a random crystallite orientation. A diffraction pattern of a similar sheet which has undergone a severe reduction is shown in Fig. 5B; the rings are broken into short arcs, the lengths of which are related to the degree of perfection of orientation of the crystallites. This material has physical properties which vary with the direction in the rolled sheet.

It also is possible from patterns of this type to estimate the internal stresses in certain materials. Such studies as these have led to the improvement of transformer steels and to the development of better rolling technique.

Annealing of rolled or drawn materials at the proper temperatures destroys this orientation and increases the size of the crystallites; along with these changes the properties of the metal are altered. It is possible to follow the growth and reorientation of the crystallites by X-ray diffraction methods.

Again, X-ray diffraction analysis may be used to determine the size of crystallites when these are below the range of microscopic visibility, as the widths of the reflections are related to the sizes of the reflecting crystallites.

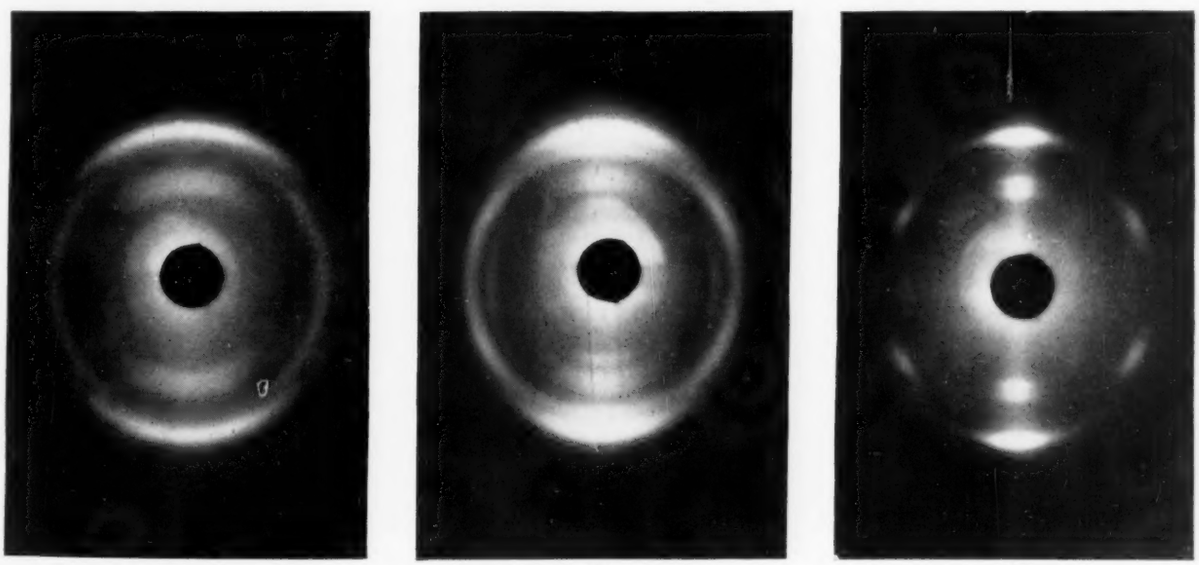
2. *Studies of Textiles.* Textile manufacturers, too, are concerned with problems of crystallite orientation. The perfection of orientation of the crystallites of fibers may be measured in the same way as for rolled metals. For example, the diffraction pattern of raw Sea Island cotton fibers, Fig. 6A, is not widely different, in the general character of the reflections, from that of lightly rolled steel. Processing the fibers may somewhat increase the perfection of orientation, as a photogram of treated cotton, Fig. 6B, shows. The orientation obtained by treating the more common cottons is not generally as perfect as that found naturally in ramie; the diffraction pattern of ramie, Fig. 6C, shows relatively sharp spots, indicating a high degree of crystallite orientation[5]. Similar studies have shown the way in which mercerization takes place.

It also has been shown that water acts upon the individual molecules of wool, while in cotton fibers it remains outside the boundaries of large groups of molecules; this has led to an understanding of the cause of wool shrinkage, and its reduction in the manufacturing processes.

In a similar manner the steps involved in the spinning of artificial fibers may be followed; X-ray studies have led to the betterment of spinning processes and the improvement of the quality of the spun materials.

3. *Ceramics.* Analogous applications are found in the field of ceramics, where one deals with systems the com-

[5]The fibers used in preparing the photograms shown in Fig. 6 were kindly furnished by Mr. C. F. Goldthwait, Industrial Fellow at the Mellon Institute.



A B C

Fig. 6. Diffraction patterns of some fibers: (A) raw Sea Island cotton; (B) treated cotton; (C) ramie.

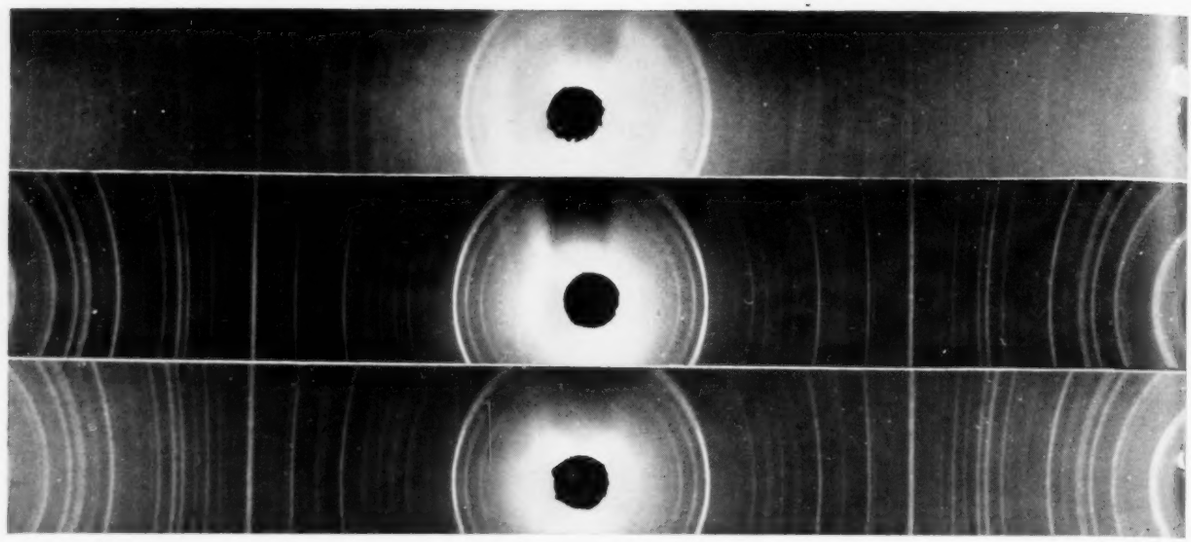


Fig. 7. Diffraction patterns obtained in a study of industrial dusts: (A) autopsy; (B) quartz; (C) factory dust.

ponents of which are compounds instead of elements. This presents no difficulty. As an example, it is interesting to observe that the components of clays may often be identified by X-ray diffraction analysis when microscopic methods prove too difficult.

4. *Studies of Glasses.* X-ray diffraction analysis has made notable contributions to the glass industry. By this means it has been shown that the coloring agents in some glasses are actually crystalline, even though they are extremely small. Certain opacifiers in glasses and enamels are found also to be crystalline. Hence the primary causes of color and opacity may be thought to be associated with extremely small crystallites of the proper substances. Thus, there is offered a means of understanding and controlling color and opacity. In a similar manner, X-ray diffraction analysis is pointing the way to the understanding of the physical nature of a clear glass.

5. *Industrial Dusts.* Finally, X-ray diffraction analysis may be used as a method of identifying compounds, just as the spectroscope is used to identify elements. Fig. 7 shows an example obtained in a study of the industrial disease known as silicosis for which quartz is often held responsible. The central pattern is that of quartz; below it is the pattern obtained from a factory dust, and above it is the pattern of the material removed, without heat or acid treatment, from a lung of a pneumonia patient after autopsy.[6] From the similarity of the positions and intensities of the lines, the conclusion is obvious.

CONCLUSION

As a tool for seeing small things, the X-ray diffraction method has led to the control of industrial processes, to the reduction of industrial wastes, to the solution of industrial research problems, to the improvement of products, and occasionally to the development of new products. Many applications could be suggested besides those given. It will not solve every problem, nor is such power claimed for it. It is probable, however, that the applications of the method have succeeded many more times than they have failed. Often valuable results have been obtained, results which were not even suspected at the beginning of the investigation.

[6]The sample used in obtaining this photogram was prepared by Dr. Olive McElroy at the University of Pittsburgh.

INSTRUMENTS' BOOK SHELF

Continued from Page 132

The Cathode-ray Tube at Work. By JOHN F. RIDER. Published by John F. Rider, 1440 Broadway, New York, 1935. Cloth, 5½x8¾ inches, 322 pages. Price $2.50.

This book covers in an excellent manner the application of cathode-rays to radio servicing, a field in which the author is pre-eminent, and also many uses in allied fields as well. It is a practical handbook intended as a reference for users of recently marketed types of commercial oscillographs.

Starting with an outline of the practical aspects of cathode-ray oscillography and with descriptions of the tubes, a complete description follows on the deflection processes. There follows a wealth of photographs of actual oscillograms, covering many circuit problems, with an interpretation of the salient features in each. These give the reader an insight into the procedure of oscillogram analysis.

Oscillograms, however, have a perverse habit of not appearing exactly as anticipated, by reason of variations in test conditions.

It is toward the solution of this problem that the author has devoted most attention. His book thus provides the means of getting experience in using this modern tool of research. Criticism which this reviewer might make would apply only to what has been omitted, and even in this matter would be unwarranted since the author has included all that he set out to do and has covered all his points in an easily understood manner without involved theories and mathematics. Little of the "How to make it" type of information has been included, since there are so many excellent outfits available which are particularly designed to fit in the servicing field. It has been the remarkable acceptance of oscillographic methods by radio amateur and servicing groups that has allowed the production of reliable equipment at reasonable prices. Much of this popularity is due to the author. The descriptions of commercial oscillographs and their practical applications will be of value to users of this equipment in many other lines of research.

R. R. BATCHER (5.4)-B-

Controlled Humidity in Industry. By M. C. MARSH. J. B. Lippincott Co., Philadelphia, 1935. Cloth, 6x9 inches, 122 pages. Price $2.50.

From his experience on the staff of the Wool Industries Research Association at Leeds, Dr. Marsh has prepared for English manufacturers of textile and other hygroscopic materials an introduction to the subject of controlled humidity in industry. Apart from its brevity, this book describes equipment on the English market; and, since England lags the United States in air-conditioning practice, this equipment is not as highly developed for specific purposes as is American equipment—so that the book cannot be recommended to Americans as an up-to-date guide to instruments, humidifiers, etc. As a non-technical review of the principles, however, Dr. Marsh's text is a lucid exposition: The topics are judiciously selected, their arrangement is progressive, and the information is conveyed without a single mathematical formula. American manufacturing executives will find this book both useful and easy to read.

M. F. BÉHAR (2.08)-B-

Load Testing on Underground Cables

By G. B. STANTON
Brooklyn, N. Y.

IN this article there will be discussed some sources of error in underground cable testing that have not been thoroughly investigated in the past; and there will be proposed some methods of determining the magnitudes of these errors and of compensating therefor in order to attain higher accuracy in this line of work even when the tests are not performed by highly skilled engineers.

A-c. and d-c. cables, designed for submarine or underground type of power transmission, have a protective metallic sheathing around the conductor-cable insulation. In general, the underground duct type cables have lead alloy sheath.

There are cases where this lead sheath acquires a potential higher or lower than that of the surrounding ground. This potential depends on the chemical condition of the ground (*i.e.*, the acidity of the soil), on the presence of other underground metals in proximity to the cables in the ducts, and on the wetness or dryness of the soil.

In congested areas of large cities other factors arise. Surface and underground electric transportation rails form a potential network. The rail potentials vary in magnitude and direction with respect to the ground potential and the nearby water, gas and electric mains.

This variation, or difference of potential of nearby metallic objects, constitutes a favorable sub-soil condition for the circulation of electrolytic currents. These electrolytic currents form a network of their own; they vary in direction and magnitude, and to a certain extent, they add to the heat generated by the conductor proper of the cable.

Most of the latest cables, installed in underground ducts, have their lead sheaths grounded or bonded. Also there are some installations with partially insulated splices and lead sheath. This practice, depending on sub-soil conditions, reduces the electrolytic sheath currents.

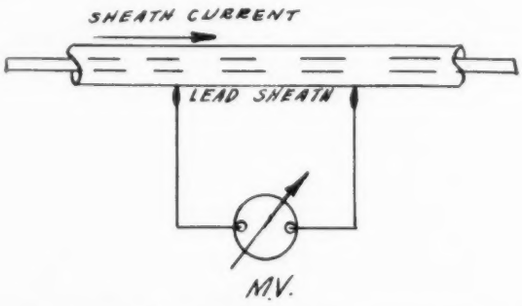


Fig. 1. Drop of Potential Method. Millivoltmeter leads applied directly to the cable sheath.

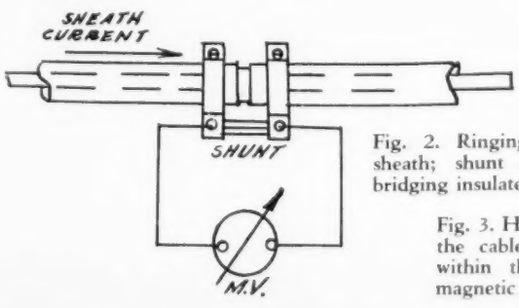


Fig. 2. Ringing of the cable sheath; shunt is clamped on bridging insulated section.

I. METHODS FOR THE MEASUREMENT OF SHEATH CURRENTS

(1) *The drop of potential method.* This method, Fig. 1, gives an approximate evaluation of the electrolytic sheath currents. The drop in millivolts across a measured length of cable is measured by a standardized instrument. The resistance of the measured length estimated by the manufacturer's data helps to give an approximate estimate of the sheath current.

(2) *A method involving the ringing of the sheath.* This method, Fig. 2, is more reliable, although not always convenient, for obtaining the value of the electrolytic currents. A small portion of the cable sheath is removed and the free ends of the sheath bridged by a suitable clamping shunt. Here again we make use of a millivoltmeter which is connected to the potential binding posts of the shunt. This will measure accurately the current through the shunt, but it requires a good metallic contact at the clamping points for the insertion of the shunt in the sheath circuit.

II. LOAD MEASUREMENTS ON D-C. CABLES WITH DEVICES ADAPTED TO SURROUND THE CABLE

There are cases where it is desired to measure the load in various feeders and mains on underground cables. These measurements are effected in manholes or service boxes when current measurements at the consumer's premises will not supply the necessary information as to the load conditions.

Instruments devised for load measurements, adaptable around the cable. These instruments are based on the magnetic induction principle.

(1) A substantially U-shaped magnetic yoke, sometimes consisting of two sections pivotally connected together, is adapted to surround the cable. The magnetic flux, produced by the current in the conductor, enters the magnetic yoke and forms a magnetic circuit. An air gap is provided in this magnetic circuit for the introduction of the measuring device. One type of instrument has a magnetic yoke terminating in pole-pieces, and a rotating direct-current armature is mounted in the air gap of the pole-pieces. The rotation of the armature cuts the lines of force in the air gap, and generates an e.m.f. which is supplied to the indicating instrument. (Fig. 3.) If the armature speed be maintained constant, the gener-

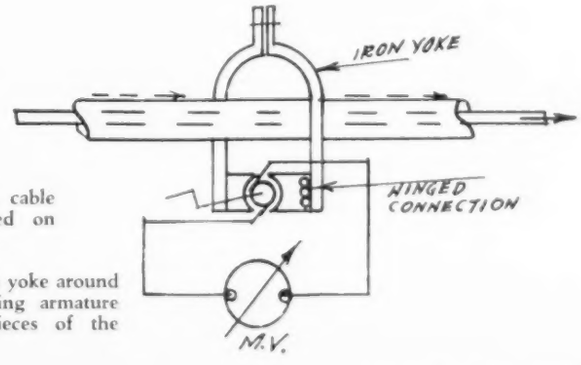


Fig. 3. Hinged iron yoke around the cable; generating armature within the pole-pieces of the magnetic yoke.

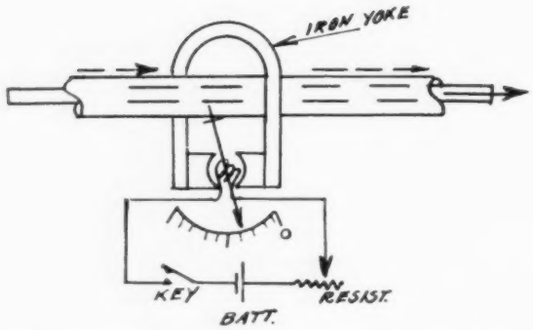


Fig. 4. U-shaped iron yoke around the cable; battery energized moving coil within the pole-pieces of the yoke.

ated e.m.f. becomes proportional to the flux in the air gap, the latter being proportional to the flux generated by the current in the cable.[1] Hence, by suitably proportioning the instrument constants, the deflections can be made proportional to the current in the cable or conductor within the magnetic enclosure. A disadvantage of this scheme is that indications depend on steadiness of hand-cranking. An automatic speed governor might help to some extent but in general the readings are unreliable.

(2) Another device, for underground direct-current measurements, comprises a U-shaped magnetic yoke having pole-pieces, and a d'Arsonval system mounted between the pole-pieces. The movable coil of the d'Arsonval system is energized by a constant-potential battery, the latter suitably located under the instrument cover. (Fig. 4.) When the magnetic yoke is applied around the cable and the movable coil energized by the battery, the instrument deflection becomes a function of the torque due to the ampere-turns of the movable coil and the flux in the air gap of the d'Arsonval system. Here again, as in the previous case, the deflections of the indicating device are proportional to the magnetic flux through the yoke, provided that the current through the movable coil remains constant.[2, 3] In this scheme the constancy of calibration depends on the steadiness of the energizing battery for the movable coil. Once the instrument is calibrated and taken out for field measurements, the battery voltage varies, and hence the instrument indications differ from the calibrated scale deflections.

(3) A recent type of measuring instrument, Fig. 5, comprises a pivotally connected magnetic yoke having an air gap in the magnetic path, and an indicating device of the movable armature type.[4, 5, 6, 7, 8] The pivotally connected magnetic yoke is applied around the cable and the movable iron of the indicating device slidably adapted in the air gap of the yoke. The deflections of this instrument depend on the amount of the flux in the air gap, said flux produced in the magnetic yoke by inductive coupling to the flux due the current in the cable. As the torque necessary for the instrument deflection is a function of the flux in the air gap and the flux induced in the movable armature by the air gap flux, the deflections of this instrument vary as a certain power of the current in the cable.

Since there is no rotating armature or energizing battery for the operation of this last type instrument, it has several inherent advantages over the first two types.

[1] W. R. Bullard, U. S. Patent No. 1,538,382.
[2] S. D. Sprong, U. S. Patent No. 1,090,419.
[3] F. W. Morris, U. S. Patent No. 1,120,217.
[4] G. B. Stanton, U. S. Patent No. 1,912,800.
[5] H. W. Hockley, U. S. Patent No. 1,924,039.
[6] British Patent No. 233,808/25.
[7] *Instruments*, Vol. 6, Feb. 1933, page 41.
[8] P. A. Borden & M. F. Béhar. Electrical Measuring Instruments and Scales. *Instruments*, Vol. 7, March 1934, page 50.

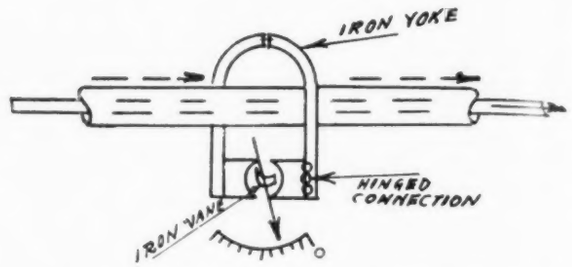


Fig. 5. Pivotally connected magnetic members around the cable; moving iron indicator slidably mounted in the magnetic path of the members.

There are several other types of instrument, intended for direct-current measurements by adapting the same around the cables. They make use of an iron yoke and a permanent magnet, either in the moving element of the indicating device or in conjunction with the yoke around the cable. The repeated disposition of these permanent magnets in proximity to heavy direct currents, alters the permanence of calibration of these instruments, and renders them not quite suitable for industrial measurements.[9, 10]

III. Effect of Electrolytic Sheath Currents on the Indication of a D-C. Instrument Intended for the Measurement of the Current in the Conductor Proper

In the previous section we have discussed instruments which are adapted around the cable. In effecting the measurement the magnetic yoke surrounds the conductor proper and the lead sheath. Thus, the flux in the magnetic yoke becomes a function of the current in the conductor proper and the electrolytic current in the lead sheath. See Fig. 6.

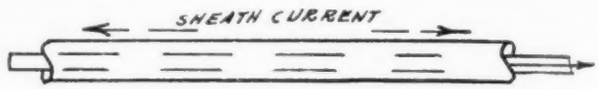


Fig. 6. Sheath currents may be in the same direction as the power current in the copper conductor, or in the direction opposite thereto.

Thus, if the conductor carries 200 amperes direct current and the lead sheath 100 amperes, both currents in the same direction, the resultant flux in the magnetic yoke becomes a function of 300 amperes d-c. Consequently, instruments discussed in the previous section will indicate 300 amperes.

If the sheath current is in the reversed direction of the current in the conductor, the resultant flux in the magnetic yoke becomes a function of 100 amperes only. Consequently the above type instruments will indicate 100 amperes.

The effect of the electrolytic current is usually overlooked in the above-discussed methods of load testing. This effect may amount to an appreciable percentage of the current in the conductor proper, and lead to an erroneous estimation of the conductor current. For more reliable measurements, instrument indications should be obtained in manholes and localities where the lead sheath or protective armor is thoroughly bonded or grounded. A still better method would be to measure the electrolytic current by one of the methods described in Section

[9] O. Knopp, U. S. Patent No. 1,015,192.
[10] H. B. Taylor, U. S. Patent No. 1,236,786.

I, and then correct the measurements discussed in Section II by the value of the electrolytic current. Although these methods involve some difficulty, they will give a fairly accurate value of the conductor current which it is desired to measure.

IV. LOAD MEASUREMENTS ON ALTERNATING CURRENT CABLES BY MEANS OF DEVICES ADAPTED TO SURROUND THE CABLE. USE OF CURRENT TRANSFORMERS

As mentioned in Section I, the sheath of the underground cable is the seat of electrolytic currents, their presence being independent of the type of power currents through the conductor proper.

In a-c. power cables, in addition to the aforementioned electrolytic currents, there is an induced alternating current circulating on the lead sheath. Since the latter is due to a.c. alone, it is a function of the a-c. power current transmitted through the conductor proper, and it varies with this current.

(1) *Power current in the conductor and induced a.c. circulating on the sheath, both in phase and devoid of harmonics.*

The usual method of load measurement, on underground a-c. cables, is practiced by adapting around the cable a pivotable split-core current transformer, whose secondary is connected to a suitable ammeter, and where the induced current bears a close ratio to that of the primary and secondary ampere-turns.

In adapting the current transformer around the cable, the transformer core surrounds the conductor and the sheath as well. Thus the induced current, in the transformer secondary, becomes a function of the resultant flux due to the power current in the conductor proper and the circulating a-c. sheath current. Assuming that the above currents are in phase and devoid of harmonics, the induced current in the transformer secondary will be the sum of these currents. Hence the indications of the ammeter, connected to the transformer secondary, will be higher, as if a higher power current existed in the conductor proper. As the a-c. circulating currents are induced all along the entire length of the cable they cause a power loss. If the cable is loaded only at the other extremity, the current in the cable will taper off toward the loaded extremity. Assuming that there are no other losses except the above, the current measured at the transmitted end will be lower than that at the generating station.

(2) *Power current in the conductor and induced a.c. circulating on the sheath, both out of phase and containing harmonics.*

When the power current in the conductor proper and the induced a.c. circulating on the the sheath contain harmonics and are out of phase relative to each other, the flux in the transformer core becomes a vector sum of the superposed currents. The ammeter connected to the transformer secondary will indicate values more complicated to decipher than in case (1).

(3) *When, in addition to the above Cases (1) and (2), the cable sheath carries electrolytic direct currents.*

In the above cases we have seen that the ammeter connected to the transformer secondary will not indicate a value truly representative of the power current in the conductor proper. If in addition, the sheath carries electrolytic direct currents, the accuracy of the current transformer and the indications of the ammeter connected to the secondary of same become still further impaired. The flux through the transformer core now becomes a function of the vector sum of the superposed d.c. and a.c., while the induced current in the transformer secondary will depend on the primary ampere-turns, the transformer winding ratio which remains constant, and the magnetizing effect of the d.c. due to electrolytic origin.

The magnetized transformer ratio will be higher, when magnetizing d-c. flux threads the core in addition to the flux due to the power current in the conductor proper. Hence, the indications of the ammeter connected to the transformer secondary will be lower than the true value, as if a lower power current existed in the conductor proper.

V. LOAD MEASUREMENTS ON A-C. CABLES BY MEANS OF DEVICES ADAPTED TO SURROUND THE CABLE, BUT DEVOID OF WINDING OR COILS

In this case we make use of instruments of the type discussed in Section II, Case (3), and which are based on the magnetic induction principle. A magnetizable member is adapted to surround the cable and a movable iron indicating device disposed in the magnetic path of the magnetizable member.

(1) If we assume conditions as in Section IV, Cases (1) and (2), on the a-c. circulating sheath currents, the indications of the instrument will be similar to a value obtainable by a current transformer.

(2) *Power current in the conductor and electrolytic d.c. on the cable sheath.*

In contradistinction to the values obtainable by a current transformer, as discussed in Case (3) of Section IV, the indications of this instrument will be higher than the actual a-c. power current in the conductor proper. The flux through the magnetic member of the instrument will be a function of the a.c. in the conductor proper, if we assume no induced a-c. circulating on the sheath, and the electrolytic d.c. on the sheath, and independent of the direction of the latter current.

Let I_{eff} be the effective of the superposed a.c. and d.c.,

I_{max} the maximum of the alternating current,

I_d the d-c. sheath current.

The effective flux due to these currents is derived by the superposed currents. Hence,

$$I^2_{eff}\, r = I^2_d\, r + \int_0^{2\pi} \frac{r}{2\pi} I^2_{max} \sin^2\theta \, d\theta$$

$$= I^2_d\, r + \frac{r}{2\pi} I^2_{max} \left[\int_0^{2\pi} \frac{d\theta}{2} - \int_0^{2\pi} \frac{\cos 2\theta}{2} \, d\theta \right]$$

Integrating and simplifying:

$$I^2_{eff} = I^2_d + I^2_a$$

$$\text{or } I_{eff} = \sqrt{I^2_a + I^2_d}$$

where I_a is the effective of the alternating current.

Hence the instrument will indicate a current value higher than the actual a.c. in the conductor proper, and the fictitious indications will be equal to the square root of the sum of the squares of the a-c. and d-c. currents.

Thus measurement of power, by adapting any of the aforementioned instruments around the cable, and under conditions enumerated in the above sections, will lead to an erratic estimation of the load conditions.

If the ringing of the cable sheath, as suggested in Section I, Case (2), is impracticable, it will be advisable to effect the measurements in bonded manholes and partially insulated cable sections.

Cathode-ray Oscillograph Auxiliaries

Tenth part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in the July 1935 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

DEFLECTION AMPLIFIERS

As the analyses of representative circuits used in commercial models of cathode-ray oscillographs bring out, it has become almost universal practice to incorporate one or more single-stage amplifiers in the equipment, for the purpose of securing greater deflection ranges. In order that this addition be useful it is necessary to minimize both the frequency discrimination (at least over the audio range) and the amplitude distortion. A high-mu pentode, such as a type 57 or a 6C6 tube, makes an excellent arrangement. A circuit showing such a stage, as outlined in Fig. 48, utilizes the same power supply that furnishes the operating voltages for the cathode-ray tube. Overload distortion is reduced by the use of ample voltage in the plate circuit with proper biasing of the control grid.

While amplification is doubtless necessary in some cases and is convenient in many, still it is desirable that direct connections to the deflection plates be made whenever possible, without an intermediate amplifier, especially when used with frequencies near the limits of the audio range or with unusual wave-forms, unless the resulting oscillograms are analyzed with frequency corrective factors applied.

For extremely low frequencies, and slowly varying currents, a conductively coupled amplifier may be used. The writer has applied such an amplifying device, the circuit of which is shown in Fig. 49, to the study of many unusual problems. It is particularly useful in certain medical and psychological studies, and in the analysis of motion in slow-moving mechanical devices. The circuit is extremely sensitive and a fraction of a volt variation in the input circuit will produce a screen-wide deflection. For even greater deflection sensitivity air-core deflection coils, having a large number of turns (see Fig. 5, Sept. 1935) can be substituted for the resistor R_2. With a similar set of coils it was found that a 3″ deflection could be obtained with about 20 millivolts applied to the input circuit.

Inasmuch as this type of circuit will find use in many of the industrial applications which will be reviewed in later articles, a few circuit details may be of interest. The input circuit as shown is an application of the resistance variation type, wherein an external resistance connected across the input terminals may vary or be varied in accordance with some set of conditions under test. R_1 must be adjusted so that the steady or unvarying input resistance is balanced out, and the first tube has a proper bias. This is indicated by securing the greatest sensitivity in the deflection circuit with a given input variation. The three-and nine-volt batteries in the input circuit can each be increased if certain tests indicate that a higher deflection gain is needed, but the preliminary adjustments should be made at the lower values. The input circuit can be readily changed to record potential variations if desired.

The voltage "e" is of the order of 10 volts, and should be variable between 6 and 15 volts for the one-megohm coupling resistor shown. Higher values of coupling resistance can be used if tubes are selected that have high internal resistance and little or no internal leakage between the elements. This is a true d-c. amplifier which will record single surges or very slow changes, and is limited in accuracy only by the freedom of the power supply from voltage drift.

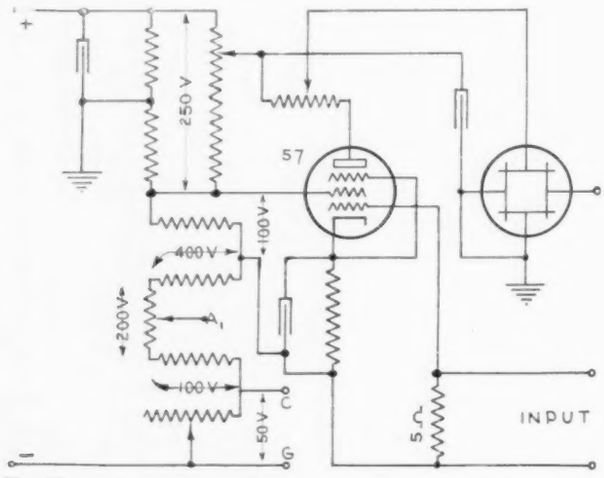
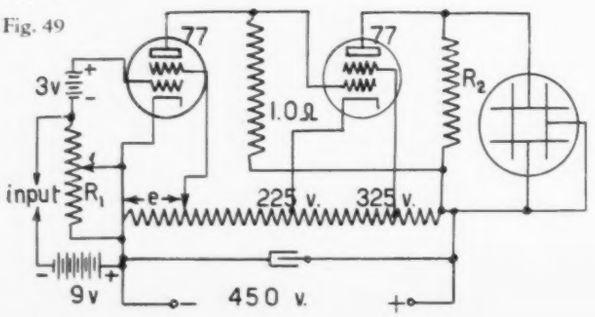


Fig. 48

Fig. 49



TRANSLATING INSTRUMENTS AND DEFLECTION ACCESSORIES.[1-7]

Since the electron deflection process in a cathode-ray tube can be accomplished only by the application of electrostatic or magnetic fields, translating devices are required to convert non-electrical magnitudes such as time, velocity, pressure, etc., into electrical potentials. It is found that many devices now available for other purposes can be utilized for such purposes without radical changes.

In problems of the usual type it may become necessary to measure such magnitudes as: physical displacements, small mechanical vibrations, fluid and gas pressures, time, sound pressure, light intensity, magnetism

[1]Sacerdote. Electrical Methods for Pressure Measurement. *Elettrotechica*, Vol. 19, 1932, pages 485-495.
[2]Schnauffer. Measurement of Oscillating Pressures. *Archiv für technisches Messen*, Vol. 1, Dec. 1931, page T83.
[3]Gerdien, Mauksch, Salomon. Cutting Pressure Measurements. *Archiv für technisches Messen*, Vol. 1, July 1931, page T6.
[4]Sachsenberg. Lathe Tool Pressures. *Zeitschrift Vereines deutscher Ingenieure*, Vol. 71, 1927, page 1609.
[5]Sachsenberg. Ultramicrometer. *Zeitschrift Vereines deutscher Ingenieure*, Vol. 72, 1928, page 469.
[6]Langer. Recorder for Small Displacements. *Review of Scientific Instruments*, Vol. 2, 1931, pages 336-342.
[7]Sucksmith. Ultramicrometer—Measurement of Small Temperature Changes. *Philosophical Magazine*, Vol. 43, 1922, pages 223-225.

and magnetic saturation, hardness of metallic objects, physiological effects such as heart and nerve actions, temperature, chemical reactions, torque, variations in rotational velocity, and many other magnitudes in other fields. Operational details concerning the application of suitable translating instruments to convert such magnitudes into electrical potentials are largely dependent on the conditions of the problem at hand. The solution of some of these problems, such as time, magnetism, etc., is evident from data which has been given in previous articles. In many of the other applications the tube may act as a simple indicator—a substitute for a measuring instrument. In many cases the use of a measuring instrument may be preferable unless the factor of time enters the problem, in which case an oscillograph is indispensable.

CONVERTERS FOR MECHANICAL MOVEMENTS.

The recording of physical displacements, or of other factors that are dependent upon such displacements, calls for a pickup suited to the distances involved. For small motions and vibrations several types of microphones, of piezoelectric devices, and of magnetic devices are available. For larger displacements, involving several inches, a linear resistance strip, the contactor of which is controlled by the master mechanism or forces under investigation, can be used to control the deflection directly. It also is possible to utilize devices wherein capacity

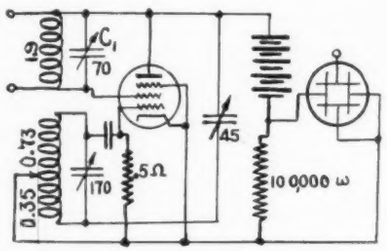


Fig. 1

changes are produced between two metal plates, by the translation of one of them by the motion under study. Such devices have been used as well in studies of small vibrations in machinery. In one system, such capacity changes are used to alter the note produced by a beat frequency oscillator; in another method they affect the balance of a neutralized amplifier stage, so as to alter the output power; in still another arrangement the capacity variations are used to alter the relative phase displacement in a rotator or circular time base circuit and thus affect the shape of the resulting ellipse. High-frequency potentials must be applied to this circuit in order that the total capacity required in the capacitive branch need not be large, and in order that the time base frequency be of a different order from the vibration frequency. In the circuit shown in Fig. 1 small changes in the capacity of C_1 are said to produce definite changes in the plate current which permit the device to be calibrated.

In many of the above applications the actual extent of the displacement is of minor importance, for such distances can usually be measured directly. The speed, acceleration and duration of the motion are generally the important factors, so that the time lag and mechanical inertia of the pickup must be considered in making a suitable selection for a particular test.

For still greater distances, of the order of a few hundred yards or more, sound waves can be employed in some types of tests. Several methods for using sound waves are applicable but the accuracy of this method, when used in the open, depends upon wind velocity and barometric pressure. In one arrangement, a sound generator (loud speaker) is energized by a series of pulses spaced at definite time intervals. The speaker is located at the remote station which may be mobile. The phase relation between the sound pickup and the initial pulse indicates the separation. For longer distances several cycles may elapse before the sound wave returns.

This principle of acoustic wave propagation is the basis of certain forms of geophysical applications, where the difference in time between the ground wave and the air wave gives a clue as to the geological conditions beneath the ground. For this service the initial sound pulse is generated by firing a charge of high explosive.

For other tests it may be possible to use the Doppler effect to show the rate at which an object is moving to or from the recording station, where the oscillograph shows the frequency variations.

Specific examples, such as marine depth measurements, will be taken up in later articles.

VIBRATION STUDIES.[8-15]

Ever-increasing diligence is displayed by manufacturers in reducing the vibrations of products which have moving parts. In this work the problem of measuring the relative amounts of vibrations is but a small part of the job, as corrective measures must be applied to unbalanced parts. This requires the determination of the location of the eccentricity, and then counter-balancing it sufficiently to pass the required vibration standards. In order to do this, vibrations in two planes must be correlated into a single diagram or indication so that the direction of the unbalance component can be definitely ascertained. In some problems, such as crankshafts, the unbalance may be near one end, so that a three-plane check is necessary, or else the balance tests must be carried out simultaneously at each end. In order that the vibrations in the two reference planes be recorded independently it is necessary that the pickup unit be decidedly directive, so as to pick up vibrations in a single plane only.

Magnetic pickup units can be designed with this object in view, and have been frequently described in conjunction with many types of laboratory and production tests. Double units with operational planes in quadrature and operating with but a single point of contact with the device under test have been made. One such system, to be described in a later article, utilizes the small double magnetic pickup unit of the Service-art Laboratories, New York, which was particularly developed for automotive service tests.

It is usually found that these devices can be most useful when applied to the deflection system (either directly or through amplifiers) in conjunction with a synchronous

NOTE—In the March article of this series, reference No. 16 on page 79 did not give the correct name of the publisher of "The Cathode-ray Tube at Work." The publisher is John F. Rider, 1440 Broadway, New York.

[8]Kluge & Linckh. Measuring Rapidly Varying Pressures with Cathode-ray Oscillograph. *Electronics*, Vol. 6, Nov. 1933, page 315.
[9]Field. Study of Mechanical Vibrations. *Canadian Journal of Research*, Vol. 8, 1933, page 563.
[10]Okoshi. Cutting Forces on Planing Tools. *Scientific papers Institute of Physical & Chemical Research*, Vol. 14, 1930, pages 193-225.
[11]Okoshi & Fukui. Cutting Action with Planing Tools by Piezoelectric Methods. *Scientific papers Institute of Physical & Chemical Research*, Vol. 21, 1933, pages 97-166.
[12]De Juhasz. The Engine Indicator. (Electrical methods.) *Instruments*, Vol. 6, 1933, pages 27-29.
[13]De Juhasz. The Engine Indicator. Instruments Publishing Co., 1934. Section on "Electric Indicators," pages 110-130.
[14]Kroon. Mechanical Tests on Turbine Blades. *Instruments*, Vol. 8, June 1935, pages 153-155, 159.
[15]Rushing. A Rapid Method for Determining and Correcting Unbalance. *Instruments*, Vol. 8, Sept. 1935, pages 228-231.

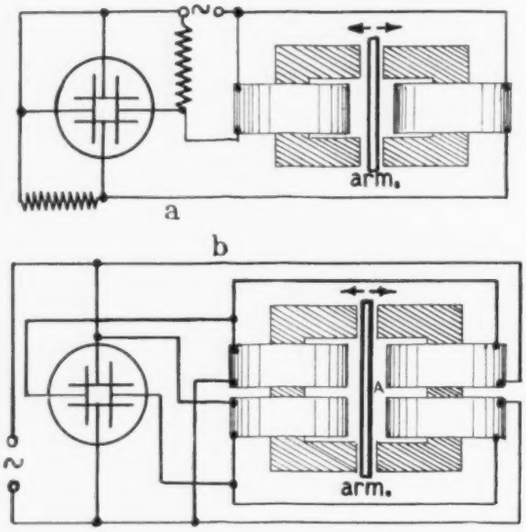


Fig. 2

circular time base operated directly by the mechanism under investigation.

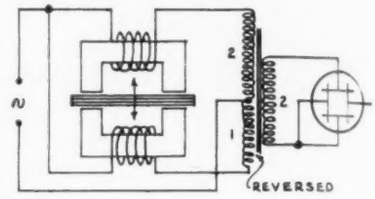
For tests involving small displacements there are sometimes available such common devices as telephone receivers, electric phonograph pickups, microphone units, etc., which, with a single-stage of electron-tube amplification, can be used for deflection control.

In some types of electromagnetic devices the output potential depends upon the rate of change of the armature motion and not on the actual displacement—a factor which must be considered in certain tests where permanent changes in the position of particular elements must be recorded, and where static loads must be measured. This condition usually occurs when the potential induced in the coils by movements of an associated armature is used for the deflection control. However, the same devices can usually be connected so that the deflections of the armature produce changes in the device. In this case a fixed frequency must be applied to the circuits which are often of the nature of a bridge circuit or a phase-shifting network. The applied frequency must be much higher than the frequency of the vibrations under investigation. In this case, however, the deflection can be calibrated in terms of the actual displacement.

Many commercial "vibrographs," "telemeters," etc., utilizing some such principle have been marketed. Fig. 2a shows one of the arrangements employed. The armature is either connected to a test prod which is applied to the vibrating mechanism, or else is attached to a weight and is inertia controlled, in which case the whole device is clamped to the mechanism under test. In Fig. 2b four similar coils are placed on a common magnetic circuit, and connected as in a bridge. With correct polarities an angular movement of a radial line of light is produced on the screen, depending upon the movement of the armature.

Two other circuits in which magnetic conversion devices of this type can be used are shown in Figs. 3 and 4. In Fig. 3 the transformer has two primaries, one of which has about twice as many turns as the other. The two windings are connected series opposing as shown.

Fig. 3



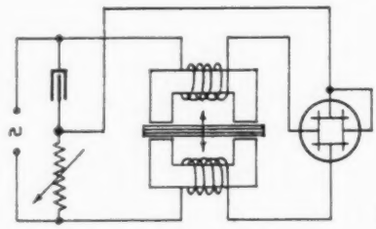


Fig. 4

The alternate changes in the impedances in each primary circuit cause simultaneous changes in the secondary voltage applied to the deflection system. In Fig. 4 the impedance variations cause changes in the phase relation between potentials applied to the two sets of deflection plates. As in other circuits the frequency of the applied potential must be much higher than the vibration frequency.

A differential magnetic unit has been described by Langer, which is also used in a bridge circuit, and is capable of accurate amplitude calibration.

A carbon block or graphite disk pile can be used in the measurement of pressure variations. Resistance changes due to compression variations can be used to control the deflection directly when deflection coils are utilized, or the changes in a voltage drop across the pile can be amplified and applied to deflection plates.

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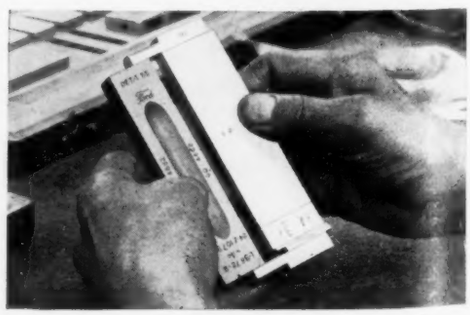

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Sources of Error in Electrical Measurements

(Concluded)

Twenty-ninth instalment of "Electrical Measurements and Control." This series began in the January 1934 issue. See announcement on editorial page of November 1933 issue. All rights reserved by the authors.

By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

2. Errors Due to the Method of Measurement

The most common errors in electrical measurement are without doubt those due to wrong methods or to neglecting disturbing conditions external to the instruments. It often happens that errors or discrepancies arising in electrical tests are blamed on the equipment used, when the real trouble lies in the manner in which the instruments are employed. These sources of error may be roughly classified as follows:

(a) Power consumption in the instruments
(b) External conditions
(c) Stray magnetic or electrostatic fields
(d) Poor contacts in instrument connctions

(a) Errors Due to Power Consumption.

The subject of power consumption in measuring instruments has received some attention in the May 1934 article with particular reference to the wattmeter, and in this regard need be only briefly reviewed here. Where current passes through the windings of an instrument, it is obvious that power must be consumed in those circuits, and where there are used simultaneously more than one instrument, such as an ammeter and a voltmeter, or two two circuits of a wattmeter, it is likely that the reading of one instrument will differ from actual conditions in the circuit under measurement by an amount de-

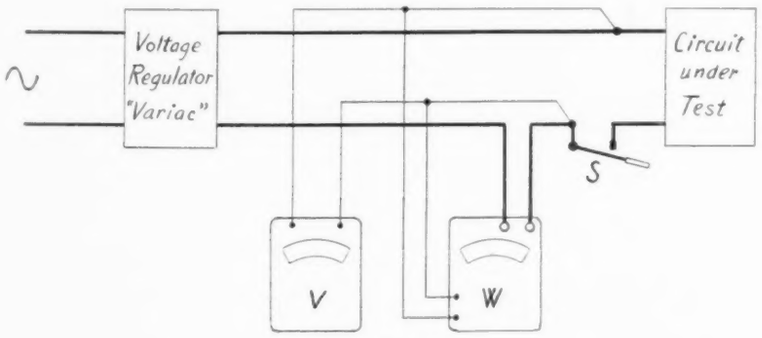

Fig. 46-3

pending upon the power consumed in one or another of the instrument windings. The power consumption of a well-designed indicating instrument will seldom exceed 5 watts, but that of a direct-acting recorder may be much higher, perhaps as much as 100 watts. Consideration of these magnitudes as compared with that of the circuit under measurement will determine the need of making allowance for such losses. The method of compensating for this source of error by the use of special wattmeter windings (treated in the June 1934 article) consists in general in providing the instrument with an auxiliary winding having the same magnetic axis as the current coil and causing the current flowing in the voltage coil to pass through this winding in a reverse direction.

A simple and satisfactory method of eliminating the error due to instrument losses when measuring power consumption on small units is shown in Fig. 46-3. Connections are made so that the current flowing in the voltage coils of all instruments in the circuit (*e.g.*, wattmeter and voltmeter) passes through the wattmeter current coil. Thus the voltage coils are all in parallel with the load under test. An observation is made under this condition, the switch is

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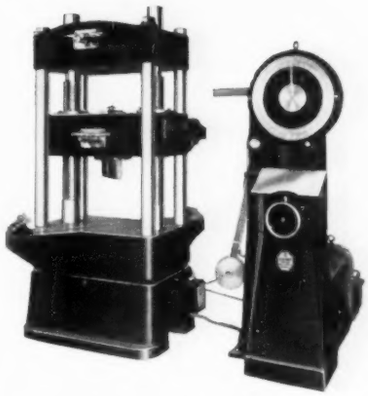

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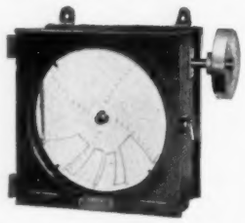

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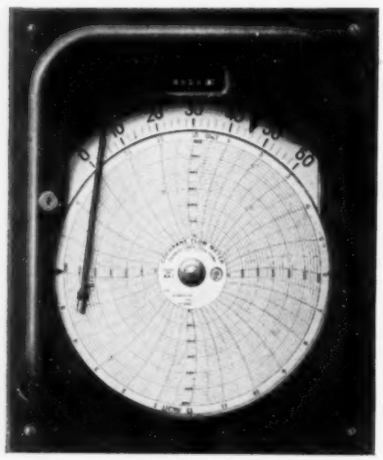

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opened, removing the load under test, the voltage adjusted if necessary to the value at which the first reading was taken, and the observation repeated. The change in reading of the wattmeter, as represented by the difference in the two observations, will be the value of power consumed by the circuit under test.

Notes on above method:

(1) On a-c. work an adjustable-ratio transformer, such as the "Variac" is an excellent voltage regulator for this purpose.

(2) While this method is permissible for measurements of power, it should not be used in the determination of current values unless it is known that the current in the circuit under test is in phase with that flowing in the voltage circuits of the instruments. Thus, since such circuits usually operate close to unity power factor, the method should not be used in determining the current flowing in an inductive circuit at a specified voltage.

(3) When power factor meters or frequency meters are used in conjunction with other instruments in a test, it may be borne in mind that in neither of these is the exact value of the voltage of importance in the reading. Such instruments, therefore, may generally be connected to the circuit at points where their current consumption need not enter into the test.

(4) Where instrument transformers are used it is seldom necessary to correct or to compensate for instrument losses.

(b) External Conditions.

It sometimes happens that one is so engrossed in the actual technicalities of his test that he neglects external conditions that may have an important bearing upon his results. The most noticeable of these are temperature changes, humidity, vibration, and, in some cases, barometric pressure. Any or all of these may have appreciable effects upon the electrical characteristics of the apparatus under test. Due cognizance should therefore be taken of any possible errors from these causes, and means provided either to remove them or to make proper allowance for their presence.

(c) Stray Fields.

A common source of instrument error, and perhaps one of the most neglected, is the stray magnetic field. Such fields are everywhere present in the vicinity of electrical apparatus, and the tester should be continually on the watch for them. With different types of instruments the effects of stray magnetic fields vary greatly in their nature and magnitude. Some types, while but little affected themselves, may be responsible for strong fields which disturb nearby instruments; while others, not themselves of a disturbing nature, are sensitive to external influence. Though the presence of stray fields is likely to be ignored by the hasty observer, thir importance as a source of error has long been recognized by authorities, and the subject has been exhaustively treated by a number of investigators.[1,5,6]

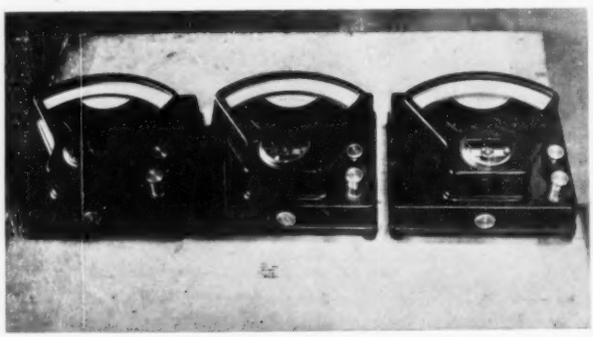

Fig. 46-4

"How not to do it"

Fig. 46-5

Instrument movements of the permanent-magnet type have strong fields of their own. They are not noticeably troubled by external weak fields. However, the field from a dynamo, or nearby permanent magnet, or electro-magnet, may produce noticeable and possibly lasting effects on the accuracy. Two such instruments in proximity may affect each other's indications by several percent; and to be sure of eliminating such errors, the instruments, unless specially designed for operation close together, should be placed from 12 to 18 inches apart. A thorough quantitative discussion of the mutual effects of d'Arsonval instruments has been given by Brooks.[1] Figs. 46-4 and 46-5 are two "how not to do it" photographs for which the authors are grateful to R. W. Squibb* who contributes also the following comments:

[5]F. B. Silsbee, *Transactions A.I.E.E.*, Vol. 48, 1929, page 1301.
[6]S. L. Gokhale, *Transactions A.I.E.E.*, Vol. 48, 1929, page 1307.
*Junior Metallurgist, The American Rolling Mill Co.

have seen three in a row (Fig. 46-4) in some of the best laboratories. This crowding makes the center instrument read about 2 percent low and the outer instruments about 1 percent low. Other workers will place their d-c. testing instruments vertical (Fig. 46-5). With Weston Model No. 1 this is not so bad but for Westinghouse testing instruments this is the worst position. I would also recommend that before installing d-c. instruments permanently, they first be connected with leads 6 or 8 feet long, and then moved around at various distances to see if indications are affected.

Powerful alternating fields, while not directly affecting the indications of d'Arsonval type instruments, may serve to weaken the magnets, and thus permanently impair the accuracy.

In instruments of the electrodynamic type, the indications will be affected only by stray fields of the same frequency as the currents in the windings. Permanent magnets, therefore, only affect the readings when the instruments are used on direct current. The movements of these instruments, unless astatically arranged, are extremely sensitive to stray fields and, if not shielded, should never be used without testing for stray fields. A simple test may be made by making observations on a constant magnitude, with the instrument in two positions 90 degrees apart about the axis of the movement. If a stray field is present the reading will differ. If the field cannot be eliminated, the error may be compensated out by averaging reversed readings. (If the instrument is a wattmeter, of course current and voltage must both be reversed.) In many standard types of electrodynamic instruments it is customary to enclose the movements in a laminated-iron shield, thus shunting stray flux around the movement and preventing its linking with the measuring system. A properly designed shield affords protection against all but the strongest fields. When a shielded electrodynamic instrument is used on direct current, it should be made a regular practice to average reversed readings in order to eliminate the possibility of error due to residual magnetism in the material of the shield.

In electrodynamic instruments of the astatic type, the windings are so disposed that a stray magnetic field from an external source links with two opposed sections of the active winding, in such a manner as to have its effect thereon neutralized. The Kelvin balance and the Thomson astatic instrument* are examples of this type. The feature of astaticism in such instruments is strictly true only when the lines of force of the stray field are substantially straight in their passage through the instrument; so the effect of the stray field from a heavy current flowing in a conductor close to the instrument may not be completely annulled by the opposed arrangement of the coils.

The induction type of instrument, having an almost completely closed magnetic circuit, is not objectionably susceptible to stray magnetic fields. Strong fields of the same periodicity as the current in the instrument may introduce errors. When these are suspected or known to be present, their effect may be eliminated, as in the electrodynamic type of instrument, by averaging reversed readings.

The action of stray magnetic fields upon instruments of the moving-iron type is somewhat complex. The torque developed in the instrument is a function of the total field acting upon the iron, irrespective of frequency, wave-form, etc. Such an instrument, therefore, carrying an alternating current in its windings, may have its readings disturbed by fluxes produced by currents of the same or other frequencies, or by permanent magnets. Fields synchronous with the magnitude under measurement may either increase or decrease the indication, while the general tendency of others is to increase the deflection. The effect of synchronous fields may, as in the electrodynamic type, be eliminated by taking reversed readings, but the only way to avoid the effects of other fields is to guard against their presence.

Sources of stray magnetic fields are much more common than might be thought. Among them may be mentioned: Permanent magnets, such as are found in d'Arsonval movements, magnetically damped instruments, meggers, watthour meters, magnetos and telephones; conductors carrying heavy currents in proximity to the instruments in use; transformers with open, poorly assembled, or saturated magnetic circuits; dynamo-electric machinery, both for direct and alternating current; circuits in nearby instruments, and magnetized tools.

Electrostatic Fields.

While the statements in the foregoing paragraphs have reference to magnetic fields only, it is to be remembered that serious errors may be introduced by electrostatic fields. The best-known instance of this, of course, is the effect which may be produced upon the pointer by a static charge induced upon the glass of the instrument by rubbing with intent to remove dust. This must be care-

Instruments, March 1934, pages 48-52.

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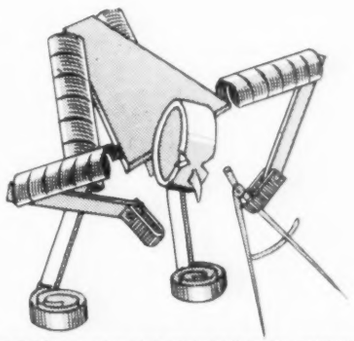

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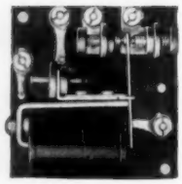
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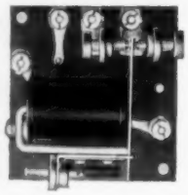
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fully guarded against, particularly in dry climates or in rooms where the air is heated but not humidified, and where suspected it may be removed by breathing upon or by slightly moistening the glass. Much of the effect of static may be eliminated by having the enclosure of the moving parts as nearly as possible a complete conducting cage. In some instruments having a case of insulating material, this is accomplished by covering the inside surfaces with a conducting film and electrically connecting this to the metal parts of the movement. At least one manufacturer (General Electric) provides a slightly conducting glass, upon which local accumulations of static are impossible.

In wattmeters having two circuits which may attain widely different potentials, or in ammeters directly connected to high-voltage lines, electrostatic forces sometimes make themselves apparent in the shape of errors of indication. Quite apart from the danger of damaging instruments so used, and of personal hazard to the user, such potential differences are undesirable from the standpoint of accuracy of measurement; and wherever possible all parts of the measuring element should be maintained at substantially the same potential.

In the measurement of small-value power at high voltages (as in determining insulation characteristics, the effects of electrostatic fields are of paramount importance. Much has been written on this subject alone, both in the form of technical articles and papers, and in recent textbooks on laboratory and field practices in high-voltage measurements.[7-13]

(d) Errors due to Poor Contacts.

Care should always be exercised to see that there are no loose connections in the measuring circuits, no matter how temporary may be the "hook-up." Such are is imperative where large currents or low voltages are involved. Loose connections carrying large currents will soon manifest themselves by undue heating. This should be particularly guarded against where shunts or instruments carrying the line current are concerned, as the high temperature may permanently affect their accuracy. The leads of shunted ammeters should always be carefully connected in and tightened up, the terminals being kept clean and bright. Special precautions in the construction and use of shunts and shunt leads have been outlined in the article* on Ammeters and Voltmeters. The leads used with portable instruments should frequently be examined to see that the individual strands are intact, and when found defective, they should at once be repaired. Shunt leads should always be used with the instrument for which they are adjusted, should be considered part of this instrument, and should not be used for any other purpose. The secondary circuits of current transformers should be made up of good wire of low resistance, and particular care should be exercised in the connections. "Test clips" should never be used in these circuits. As has previously been emphasized† the introduction of abnormal resistance or of open circuits into current transformer secondaries is dangerous not only to the equipment but to the operator.

3. Errors of Observation

Errors arising from he method of reading an instrument are exceedingly variable, and depend upon two important factors: the construction of the instrument and the skill and care of the observer. High-grade portable instruments are provided with a mirror beneath the pointer. Here the reading is made by observing with one eye the position of the pointer at the time that it either splits the reflection of the observer's eye or hides its own reflection. If the pointer be twisted, and repair is for any reason not practicable, the readings may be made by selecting one convenient point or edge near the tip and using that in all observations. Mirrorless indicating instruments should be read with the eye as near as can be estimated on the axial line of the movement. The effect of scale proportionality on observational errors has been fully treated

[7]C. T. Weller, 132-kv. Shielded Potentiometer. *Transactions A.I.E.E.*, Vol. 48, 1929, pages 790-807.
[8]H. L. Curtis. Shielding and Guarding Electrical Apparatus. *Transactions A.I.E.E.*, Vol. 48, 1929, pages 1263-1270.
[9]Dawes, Hoover and Reichard. Some Problems in Dielectric Loss Measurements. *Transactions A.I.E.E.*, Vol. 48, 1929, pages 1271-1285.
[10]J. G. Ferguson. Shielding in High-Frequency Measurements. *Transactions A.I.E.E.*, Vol. 48, 1929, pages 1287-1293.
[11]E. E. Salter. Guarding and Shielding for Dielectric Loss. *Transactions A.I.E.E.*, Vol. 48, 1929, pages 1294-1300.
[12]B. Hague. A-C Bridge Methods. Pitman Publishing Co., 1932, pages 358-371.
[13]F. R. Benedict. Bridge Methods for Measuring Dielectric Power Factor and Capacitance. *Instruments*, Vol. 7, May 1934, pages 84-86.
*Instruments, May 1934, pages 95-96.
†Instruments, April 1934, page 73.

in a recent article by Jewell[14] from which Figs. 46-6 and -7 are reproduced. The former shows the observational error in percent of the indication caused by an error of 0.005 inch on a 6-inch scale for various scale distributions as a function of the pointer deflection measured in inches. The latter shows the observational error in percent of the indication caused by an error of 0.005 inch on a 6-inch scale for various scale distributions as a function of the pointer deflection measured in volts. Heavy lines show scale regions which are "open" and above one-third of the scale length.

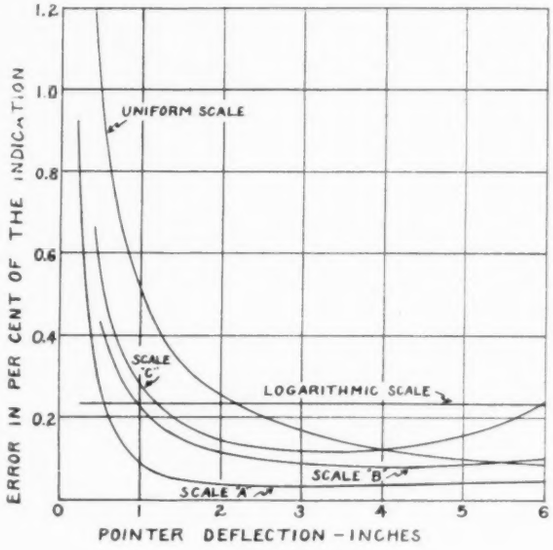

Fig. 46-6

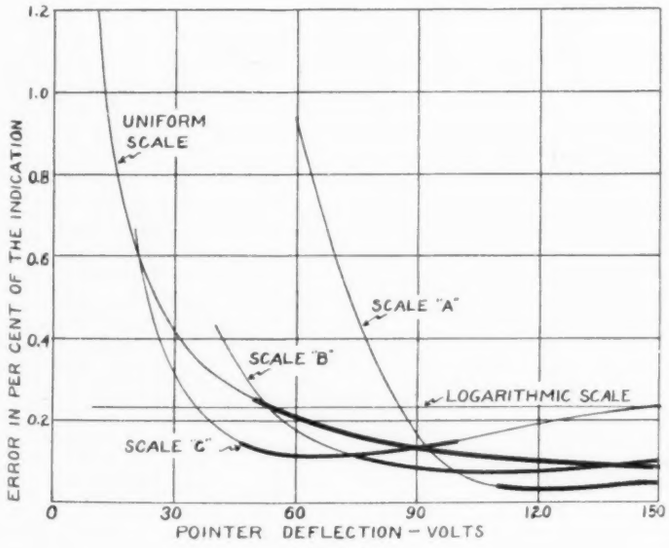

Fig. 46-7

Mistakes are sometimes made in the use of instruments having several ranges by reading the wrong scale or by allotting wrong values to scale divisions. These can be obviated only by proper care on the part of the user.

In any series of measurements of the one magnitude we find that, owing either to imperfections in the instruments or to personal errors in making observations, results will differ slightly from one another. Errors of observation are as likely to be positive as negative, and, if a sufficient number of readings are taken, may in the long run be considered as having little influence upon the final result. The greater the number of individual observations, the less will their mean deviate from the true value. Operating conditions and the degree of accuracy desired will in each case determine the number of observations to be made.

[14] R. G. Jewell. Instrument Scale Distribution and its Effect on Observational Errors. *Instruments*, Vol. 8, March 1935, pages 58-60, 79. Discussion by H. B. Brooks. *Instruments*, Vol. 8, April 1935, page 102.

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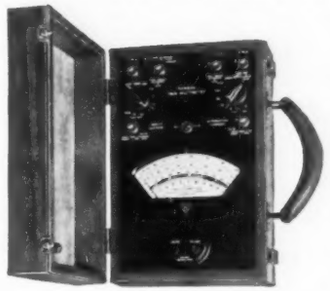

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ADVERTISERS' INDEX

American Meter Company	Inside back cover
Amthor Testing Instrument Co., Inc.	144
Bailey Meter Company	124
Baldwin-Southwark Corporation	Inside back cover
Bausch & Lomb Optical Co.	A9
Bristol Company	Back cover
Brown Instrument Company	A6-A7
Chace Co., W. M.	A11
Clifford Mfg. Co.	125
Cochrane Corporation	144
Continental Electric Company	145
Eppley Laboratory, Inc.	A14
Federal Products Corp.	A14
Fish-Schurman Corp.	126
Ford Motor Co., Johansson Div.	142
Foxboro Company	A2
Friez & Sons, Julien P.	125
General Plate Company	145
General Radio Company	A14
G-M Laboratories, Inc.	127
Gordon Co., Claud S.	A12
Illinois Testing Labs., Inc.	148
Johnson Service Company	127
Johansson Gage Div., Ford Motor Co.	142
Kurman Electric Company	146
Leeds & Northrup Company	A1, A10
Leitz, Inc., E.	128
Littelfuse Laboratories	150
Minneapolis-Honeywell Regulator Co.	A6-A7
Pfaltz & Bauer Co., Inc.	146
Pioneer Instrument Company	128
Powers Regulator Co.	Inside front cover
Pyrometer Instrument Company	147
RCA Mfg. Co.	Inside back cover
Radio & Technical Publishing Co.	148
Rawson Electrical Instrument Co.	147
Review of Scientific Instruments	A13
Riehle Div., Am. Mach. & Metals Mfg. Corp.	135
Roller-Smith Company	A14
Rubicon Company	149
Russell & Co., C. E.	148
Shallcross Mfg. Co.	149
Struthers Dunn, Inc.	A11
Taylor Instrument Companies	A3
Triplett Electrical Instrument Co.	A11
Trofimov School of Inventive Practice	148
Ward Leonard Electric Co.	A11
Westinghouse Elec. & Mfg. Co.	A5
Weston Electrical Instrument Corp.	A8
Winslow Engineering Co.	148

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MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm.

D134 **Instruments for Crime Detection.** Bulletin D-17, 24 pages, illustrates the applications of Microscopes for identification of finger prints, bullets, etc. Bausch & Lomb Optical Co., 615 St. Paul St., Rochester, N. Y.

D135 **Laboratory Equipment.** 500-page Catalog No. 45, entitled "Laboratory Equipment for Chemistry, Metallurgy and Physiology," lists thousands of items, many of which are new. Selection was based on items of proven merit following to the greatest possible extent the specifications of the ACS, ASTM, OCS, API, U. S. Government Bureaus, etc. Equipment is grouped according to use in industry. Chicago Apparatus Co., 1735 N. Ashland Ave., Chicago, Ill.

D136 **Industrial and Scientific Instruments.** Two new 64-page catalogs which deserve special mention for factual exactitude and restrained tone of text—in some instances almost amounting to understatement: Bulletin "D" covers barometers, altitude standards, vacuum gages, draft gages, siphon gages, ammonia gages, manometers, mercury gages, tank gages, photometers, gavitometers, calorimeters, Orsats, tachometers, rain and snow gages, anemometers, water gages, hot plates and miscellaneous instruments. Bulletin "H" covers hygrometers, psychrometers, registering thermometers, outdoor and indoor thermometers, barometers, rain and snow gages and meteorological instruments. Precision Thermometer & Instrument Co., 1434 Brandywine St., Philadelphia, Pa.

D137 **Temperature Control Devices and Accessories.** 40-page Bulletin "T" covers thermostats, thermoregulators, temperature controls, relays, wiring diagrams, orchard alarms, constant temperature baths and thermometers. Precision Thermometer & Instrument Co., 1434 Brandywine St., Philadelphia, Pa.

D138 **Combustion Indicator.** Form 4035 describes the Moto Vita, instrument which indicates the combustion efficiency of any engine by an accurate and instantaneous analysis of the products of combustion. Moto Meter Gauge & Equipment Corp., Toledo, Ohio.

D139 **General Radio Experimenter.** March issue contains descriptions of: a new precision wavemeter, radio frequency bridge and a direct-reading condenser for substitution measurements. April issue contains the following articles: better mixer controls; direct measurements with General Radio instruments; the frequency standard at General Radio Co. General Radio Co., 30 State St., Cambridge A, Mass.

D140 **Balanced Pressure Rotameter.** 1-page leaflet illustrates and briefly describes this flow meter for handling corrosive liquids, vapors and gases at pressures where the use of an instrument having an exposed glass metering tube would be dangerous. Schutte & Koerting Co., 12th & Thompson Sts., Philadelphia, Pa.

D141 **Utility Thermometers.** Bulletin W illustrates and describes various types of hygrometers and thermometers. Prices are incuded. Consolidated Ashcroft Hancock Co., Bridgeport, Conn.

D142 **Spectrometric Equipment.** 32-page Catalogue D-221 discusses the basic theory and design of spectroscopes, illustrates various models, and includes price list. Bausch & Lomb Optical Co., 615 St. Paul St., Rochester, N. Y.

D143 **Sand Testing.** Leaflet illustrates instruments for the determination of moisture, permeability, strength and hardness of foundry sands. Harry W. Dietert Co., 676 W. Grand Blvd., Detroit, Mich.

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D144 **Constant Pressure Megohmer.** 4-page Bulletin No. 415 lists the features of the Junior Paragon Constant Pressure Megohmer. Data on ranges are included. Herman H. Sticht & Co., 27 Park Place, New York, N. Y.

D145 **Controlled Rectifier.** Ward Leonard Electric Co., 38 South St., Mount Vernon, N. Y., announces a new controlled rectifier "Bulletin 8851" providing the "Ward Leonard System" of control for a d-c. motor from an a-c. power supply. This system of control permits a very gradual acceleration of the motor to any desired speed with the motor speed maintained constant under all conditions of permissible motor loads.

D146 **Oil Circuit Breakers.** Catalog 6, Sections 2 and 4: Section 2 covers all parts common to all hand-operated breakers such as face plates, attachments and accessories and dimensions; Section 4 is devoted to small breakers having interrupting capacity ratings $< 50{,}000$ kva. Roller-Smith Co., 233 Broadway, New York, N. Y.

D147 **Rheostats.** Bulletin 1450 gives specifications and prices for Jagabi Rheostats. James J. Biddle Co., 1211 Arch St., Philadelphia, Pa.

D148 **Combustion Recorders.** Catalogue RA-346 covers the complete line of combustion meters manufactured by the Hays Corp., Michigan City, Ind. It contains a complete description of the instruments and engineering data on their application.

D149 **Recording Thermometers.** Bulletin 198. An attractive 48-page bulletin in 2 colors devoted to thermometers for every industrial use. The various types are illustrated and a number of installations are shown. Data on the "Uni-Ambi" and "Anti-Ambi" are included. The various accessories, such as bulbs, sockets, bushings, flanges, etc., are also covered. Foxboro Co., 46 Neponset Ave., Foxboro, Mass.

D150 **Thwing's Paper Tester.** The first issue of this new house organ, which will be published every two months by the Thwing-Albert Instrument Co., 3339 Lancaster Ave., Philadelphia, Pa., deals with checking the basis weight of paper. It is stated that subsequent issues will deal with additional topics of interest to the manufacturers and users of paper and paper products. The articles will be written by outstanding authorities in the paper industry.

D151 **Temperature Control.** Bulletin 443, an attractively printed direct-mail folder illustrates the Model 240M recording thermometer and the "Free-vane" recording temperature controller. The Bristol Co., Waterbury, Conn.

D152 **Instruments from the Executive Viewpoint.** This 24-page booklet illustrates and briefly describes the part instruments and controls play in the modern industrial plant. Brown Instrument Co., 4482 Wayne Ave., Philadelphia, Pa.

D153 **Taylor Rochester.** The Fall-Winter 1935 issue of this house organ contains a large number of articles on the application of instruments to meteorology. Taylor Instrument Companies, Rochester, New York, N. Y.

D154 **Instruments for Measurement and Control.** 16-page catalogue illustrates the complete line of instruments (slide wire rheostats, galvanometers, galvanometer relays, photoelectric cells, phototube relays and control apparatus, phototube accessories, etc.) manufactured by the G-M Laboratories, 1732 Belmont Ave., Chicago, Ill.

D155 **Optical and Mechanical Precision Instruments.** A 52-page book printed in 2 colors, in English, illustrates and describes the optical and mechanical precision instruments manufactured by Officine Galileo, 29, Viale Eginardo, Milano, Italy.

D156 **Surface and Needle Pyrometer.** Bulletin 60-A illustrates the various types of new surface and needle pyrometers of the Pyrometer Instrument Co., 103-107 Lafayette St., New York, N. Y.

D157 **Unit Regulator.** Bulletin No. 105 illustrates the principle on which the Askania Unit Regulator operates. The Askania Jet Pipe is shown by means of a diagram. Bulletin No. 104 illustrates the jet pipe regulator, the control cylinder, the pump unit and the regulator mountings. Askania Regulator Co., 1603 S. Michigan Ave., Chicago, Ill.

D158 **Micromax Speed Recorders.** Folder N-27 describes the Micromax speed recorder. New tachometer magnetos are illustrated and described. Leeds & Northrup Co., 4955 Stenton Ave., Philadelphia, Pa.

D159 **Water Flow Alarm Service.** 4-page folder illustrates a flow indicator which can be used for local water flow alarms and sprinkler supervisory systems. The Autocall Co., 434 Tucker Ave., Shelby, Ohio.

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Foxboro Co.
Friez & Sons, Inc.
Taylor Instrument Cos.
Pressure-Temperature
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Bristol Co.
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Cochrane Corp.
Foxboro Co.
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Pressure & Vacuum
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Cochrane Corp.
Foxboro Co.
Friez & Sons, Inc.
Taylor Instrument Cos
Rain
Friez & Sons, Inc.
Taylor Instrument Cos
Recording—Distance
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Bailey Meter Co.
Bristol Co.
Brown Instrument Co
Cochrane Corp.
Foxboro Co.
Friez & Sons, Inc.
Leeds & Northrup Co.
Pioneer Instrument Co.
Taylor Instrument Cos.
Strain
Baldwin-Southwark Corp
General Electric Co.
Vacuum
Continental Elec. Co.
Bristol Co.
Brown Instrument Co
Foxboro Co.
Friez & Sons, Inc.
General Electric Co.
Taylor Instrument Cos
Volume
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Wind
Bristol Co.
Brown Instrument Co.
Friez & Sons, Inc.
Taylor Instrument Cos.
Wire
Federal Products Corp.

GAGE BLOCKS
Ford Motor Co.

GALVANOMETERS
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Brown Instrument Co.
General Electric Co.
G-M Labs., Inc.
Kurman Electric Co.
Leeds & Northrup Co.
Rawson Elec. Inst. Co.
Roller-Smith Co.
Rubicon Corp.
Taylor Instrument Cos.
Triplett Elec. Inst. Co.
Westinghouse E. & M.Co.
Weston Elec. Inst. Corp.

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GAS ANALYTICAL METERS
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Electrical
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American Meter Co.
Bailey Meter Co.
Foxboro Co.

GAS LEAK INDICATORS
Pioneer Instrument Co.
Taylor Instrument Cos.

GAS-METERS
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Bailey Meter Co.
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Foxboro Co.

Wet Test
American Meter Co.
Foxboro Co.

GLASS STRAIN TESTERS
Gaertner Scientific Corp

GOVERNORS
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Bailey Meter Co.
Bristol Co.
Brown Instrument Co.
Foxboro Co.
Taylor Instrument Cos
Pump
Bailey Meter Co.
Taylor Instrument Cos

GRAVITOMETERS
American Meter Co.

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Roller-Smith Co.
Weston Elec. Inst. Corp

HARDNESS TESTERS
Baldwin-Southwark Corp
Riehle Div. Am. Mach.

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